Science News

VI

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1948

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Contents

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We wish to thank Glaxo Laboratories Ltd., of Greenford, Middlesex, for permission to reproduce plates 13 to 22 showing the production of Penicillin, and the Central Office of Information for providing plates 1 to 4 on the Antarctic

CORRECTION

In a note on partition chromatography (S.N 4 page 67) the method is described as due to Dr. Martin and Dr Synge of the Lister Institute. Dr. Martin is actually working on behalf of the Wool Industries Research Association, Leeds, who financed the research, and we apologise to them for omitting mention of their name.

Editorial

What is News, speaking scientifically? Newspapers, which rarely have any inkling of science, love Truth Drugs and Death Rays and two-headed calves; or the latest experiment on chilblains or cancer which they can blare out as *The* Cure. If they are not sensational, they usually offer instead a little pellet of undigested facts and figures which persist without meaning in the reader's head: the horse-power of a new engine, or oil production last year, or the number of hairs on a bee's wing. It is obvious indeed that the place to look for the latest discoveries in the scientific world is not in the pages of a newspaper—for the simple reason that most journalists never have any scientific knowledge to help them understand and assess this kind of news, and are therefore bound to blunder. The only place to look is in the pages of a learned journal, written by scientists for scientists and consequently not the safest spot for the novice to linger in unguided. We draw our material from these journals, and try to act as some kind of guide by applying standards of selection Our experts try to assess the trustworthiness of the information published before passing it on. Sometimes they wait a year or two, to see if a discovery boldly announced is confirmed as correct by subsequent events. For speed and hurry have no place in scientific news. All one sweeps up in a scoop is red herring.

In our view scientific news is of three kinds. Partly it is a summary of what scientists are thinking and talking about just now, what's cooking in the Labs; what subjects they are investigating, *not* the detailed results of that investigation. Here it is the current atmosphere, the scientific weather, that we are out to report, and that is the function of articles such as "Physics Front" by A W. Haslett.

Sometimes a particular problem or subject is worth a more extended analysis In "Problems of Nuclear Physics", Prof. Peierls sets out to show what aspects of the nature of matter are engaging the attention of physicists to-day. Atomic energy and the atom bomb are engineering topics *now, have passed out of the hands of fundamental physicists.* They are primarily interested in the next term of the analysis of matter in the sequence "Matter is composed of atoms which are composed of electrons and nuclei which are composed of . . ." And their interest is a second kind of reporting

But thirdly, and most important part of all in science news, is the pause to look back over the last few years, to collect up the facts and ideas which have become established, to see how far we have now progressed in this field of research or that, where we stand at the stocktaking. Articles like "Glaciers", "Diatoms", "Making Penicillin" attempt this function of review. They are not last month's or last year's discoveries, or even the results of the last five years' work. Nor do they contain the last words on their subjects They are attempts to make the reader aware of the present state of knowledge so that he can be ready to assimilate the next step, or even perhaps make that step himself.

Turn the page, and see our policy in practice.

Report on Antarctica

BY DR. GABRIELE RABEL

1. INTRODUCTION · EARLY EXPEDITIONS

It is surprising to hear that thirteen nations in recent years have been arranging, or planning, expeditions into the remote, ice-bound and barren south polar regions—more surprising still to learn that this zeal is partly due to a political motive, the desire to secure a slice of this unpalatable ice-cake. Why? No one knows. So far there is little indication of the presence of uranium or other heart-stirring mineral wealth waiting to be brought to light. It makes me think of a woman who joins a queue without knowing what she is queuing for. Several countries look back on a century of antarctic discovery and research, but the interest of others is of quite recent date.

At present, the political divisions on the map are as follows.

There is a British sector called the Falkland Islands Dependencies, situated in West Antarctica (20–80° W), nearest to South America. It includes South Georgia and the S. Sandwich Islands which Captain Cook discovered in 1775, also Desolation, Deception and the New Shetland Islands where Edward Bransfield sent out boats in 1819, that he "might plant the Jack and take possession of the land in the name and behalf of H.M. George IV, his heirs and successors." Bransfield, it is true, "had very faint hope of ever being able to speak well of its fertility", but his party noted "a beach with seals so stowed in bulk that it seemed dangerous to approach them", which suggested "a lucrative trade in these creatures of great size, full of oil with the finest furs", the shores crowded with pe-

"disputing possession with the human visitors, who could not advance until a great slaughter was made and a lane cut through them", "immense shoals of sea elephants asleep", and "numerous whales, but excessively lean and poor."

Seal and whale hunting was mainly responsible for the first exploration of the antarctic regions. A sealer from Connecticut, Mr Palmer, visited in 1821 what the Americans call now the Palmer Archipelago and the Palmer Peninsula. A famous London whaling and sealing firm, Enderby Brothers, encouraged its masters, including Briscoe, Balleny and Weddell, whose names we also find on the map, to explore the southernmost waters.

Graham Land, all the islands around, and on its eastern side the mysterious Weddell Sea and Coates Land are within the British sector. Then, to the east, there is a Norwegian sector called Queen Maud Land.

Further east again there is a very large Australian sector, the scene of Sir Douglas Mawson's labours and, cut out of it, a strip of French territory called Adelie Land nearest to Tasmania. This was annexed only in 1924, but first visited by the Frenchman d'Urville in 1840. Of other French expeditions the best known are those of Dr Charcot, son of the celebrated physician, who cruised between 1903–1913 in his ship "Pourquoi pas?" on the west coast of Graham Land and discovered Charcot Island.

The turn of the century ushered in a series of purely scientific journeys, not followed by any annexation claim. From Belgium sailed the "Belgica" under Captain de Gerlache with Amundsen and Dr. A. F. Cook on board. From England sailed the "Discovery" under Commander Scott with Lt. Shackleton and Dr A. E. Wilson on board. From Sweden sailed a party under Dr Nordenskjold. From Germany came the ship "Gauss" built by the German Government for the purpose, under Professor Drygalski, who named a mass of volcanic rock the "Gaussberg" and a stretch of land "Kaiser Wilhelm Land". Drygalski and Scott co-operated in their magnetic and meteorological

observations. Another German, Professor Filchner, penetrated deep into the Weddell Sea and tried to survey what is now called the Filchner Ice Shelf. Many may still remember the dramatic contest for reaching the South Pole. Shackleton (1907) desired to discover both the magnetic pole, which he did, and the geographic pole, which he nearly did. When Scott set out in 1910 with a large staff of scientists, his main objective was to reach the pole. But to his dismay, he found that Amundsen had been there a month before, on December 14th, 1911. Scott, with four others, including Dr. Wilson, the chief scientist, died a horrible death from exhaustion and cold.*

An expedition of another type was sent out in 1938 by Herr Goering. The members alighted only on the edge of an ice shelf, but they took very interesting photographs from the air, and they circumscribed a bit of Lebensraum (in the western part of Queen Maud Land) which they called "Neu Schwabenland", by dropping around it flags attached to arrows.

The Argentine Government, which has maintained a meteorological station in the S. Orkney Islands since 1903, when the Scotsman Dr. Bruce installed it, bases a claim on this fact, and its geographical proximity. Chile, by a pronouncement of 6 November, 1940, simply "decreed that all lands, islands, reefs, glaciers . . . in the sector between 53° and 90° W constitute the Chilean Antarctic."

Peculiar is the political attitude of the United States. American merchants such as Mr. Palmer were among the antarctic pioneers. In 1839, the U.S. Navy despatched Comm. Wilkes on a voyage of discovery round the world, and cruising towards the south pole, he saw land "and gave the land the name of Antarctic Continent." A century later occurred the well-known private enterprises of Admiral

* Thirty miles from the pole, Scott wrote in his diary: ' . . the only appalling possibility is the sight of the Norwegian flag forestalling ours,' and three days later at the pole: 'Great God! this is an awful place, and trouble enough for us to have laboured for it without the reward of priority.'

sisted of scientists, and they had a tough job with their "Penola", a retired Breton fishing boat which soon developed engine trouble and had to travel under sail alone for hundreds of miles. Surprisingly, the Byrdians, though their official grant was vastly larger, complain too about having to drop some of their aims for want of money and about the necessity of unloading sledges, building houses, training dogs, repairing clothes and machinery which impaired their scientific work. There are no natives in Antarctica whose services can be enlisted!

For the last twenty years the centre of all polar activities in Britain has been the Scott Polar Research Institute in Cambridge It was founded in 1926 and moved in 1934 into a building of its own, a building on a fine site, pleasant to look at and dignified Owing to rich gifts of pictures and books, the house is too small already.

First director was the geographer Professor Frank Debenham. He retired in 1946 and was replaced by the Reverend W L S Fleming, Dean of Trinity Hall, a geologist and glaciologist who was one of the Grahamers and took part in other expeditions. The Committee of Management is a University body, but the Royal Geographical Society nominates one member

Dr. H R. Mill has transferred to the Institute his valuable Antarctic book collection, Dr. Wilson's water colours are also there, further manuscripts, records, maps, samples of polar equipment, etc —the task of the Institute being to collect all possible information about polar matters and to make it available to all who seek it During the war, Government Departments and private industrial firms consulted the experts about cold weather clothing and equipment, and how to make and pack things destined to endure extremely low temperatures.

One way of spreading the acquired knowledge is the *Polar Record* which appears normally twice a year. The present article owes much to the *Polar Record* as well as to personal information by Mr. Fleming

2. THE TECHNIQUE OF POLAR TRAVEL

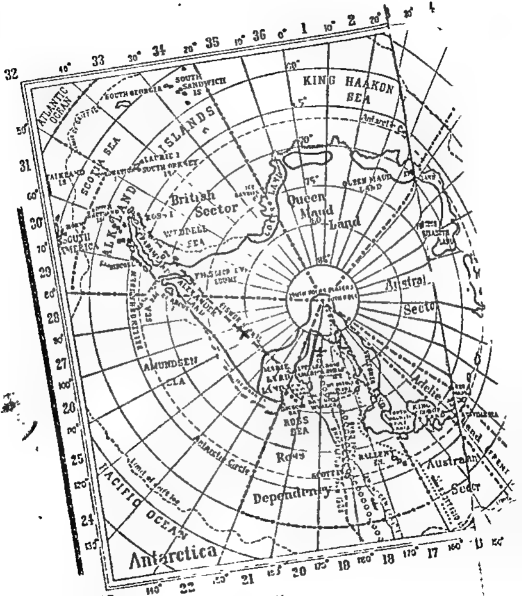
Weather and Acclimatisation

Every description of antarctic journeying abounds with complaints about the weather which assures safe travelling, even in the short summer season, for only a few days. Here is what the Byrdians say about their East Base: "If there were light westerly winds, low clouds and fog would lie for weeks over the ground... When winds were from the east or south, the sky was clear and it was necessary to seize the opportunity for a flight quickly, because as the air poured down the coastal passes from the plateau, the velocity at the base built up dangerously. There were only elusive periods of suitable flying weather." And imagine what this constant "poor visibility" means for sledging parties for whom an abyss may wait just round the corner. Sir Douglas Mawson describes "drifting snow which poured fluid-thick over the landscape, for many days it was impossible to see one's hand held at arm length. Such weather lasted almost nine months "

Blizzards may break out suddenly with tremendous violence and cease just as abruptly, but winds of two miles a minute have been recorded as lasting for many hours. It is not so much the cold which causes pain as the wind.

The temperature, especially on the Ross Ice Shelf, frequently dropped to seventy degrees or more below freezing point Two of the Byrdians, P. Siple and Ch. Passel, established that the sensation of cold and heat, and hence the feeling of comfort, does not depend on the absolute temperature of the skin but on the rate at which it loses heat to the surroundings. Touching metal or snow with bare hands burns the flesh like a hot stove, because these objects carry the heat away so rapidly.

Siple and Passel measured the time needed for a quantity of water to freeze under varying conditions of wind, etc., and built on their results a formula as well as a gadget called the "Relative Comfort Thermometer". If the


ATLANTIC OCEAN
SOUTH GEORGIA
SOUTH SANDWICH IS
KING HAAKON SEA
SCOTIA SEA
ISLANDS
SOUTH ORKNEY IS
British Sector
Queen Maud Land
QUEEN MAUD LAND
WEDDELL SEA
SOUTH AMERICA
Austral Secto
ALEXANDER LAND
AMUNDSEN SEA
ROSS SEA
Ross Dependency
Adelie Land
Australian Sector
Antarctic Circle
Limit of drift ice
PACIFIC OCEAN
Antarctica

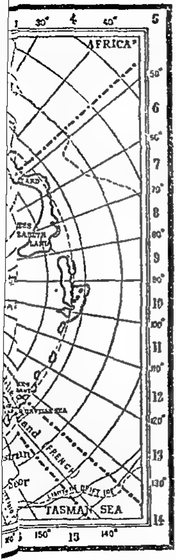


Fig. 1. The South polar end of the Earth. The *geographical* south pole lies right in the centre of the map, and the *magnetic* South pole is about 1,300 miles away (to the North of it) near the edge of the Antarctic Continent in sector 16, the Australian sector. To get some idea of the scale, find Cape Horn, the southernmost tip of South America in sector 30, it is approximately 2,500 miles from the Pole as the crow flies. Another indication of size is that the British Isles, drawn on the same scale, would fit very easily inside the innermost circle (Latitude 85°S) round the pole, with plenty of spare room

A similarly-drawn view of the North Pole would look totally different: there is nothing but sea, frozen or otherwise, within the circle of 85° N, surrounded at varying distances out to the Arctic circle by land masses. Three-quarters of Greenland, for instance, lies between Lat. 85° and the Arctic circle, while the *coast-line of Siberia is mostly between* 50° and 60° N. If they were transferred to the same latitude south, they might come alongside Cape Horn, or absorb South Georgia, and would be mostly within the limit of the Southern Drift Ice.

Alexander Land is now known to be an island of only small extent, since King George VI Sound bends round northwards into the sea near Charcot Island.

velocity increases from zero to 20 miles an hour, the rate of cooling increases by 75 per cent, but above this velocity cooling does not increase, and in a gale the temperature even rises

Heat loss by respiration may be 54 calories per day in the tropics, but 270 in very cold climates, for the incoming air must be warmed by 30–40 degrees in the lungs, as well as saturated with water as it is excessively dry.

Fatigue develops less quickly in cold climates than when the body is overheated by perspiration. Like a mechanical engine, the body seems to work best when the heat is rapidly carried away

The first year the men wore their heaviest clothes and shivered in summer. The second year they worked stripped to the waist at 0° C

There is no flu or other disease carried by germs in the Antarctic, but frost bites seem unavoidable when "fiddling" with apparatus outside The worst for the Byrdians was toothache because their fillings contracted and fell out. Finally Dr Siple invented a non-contracting mixture

Principles of Clothing and Food

The chief principle of clothing is to retain the natural heat of the body and not to let it escape In a completely insulated house we should need no fires at all Our own body heat would suffice to keep us warm Air is a bad conductor of heat, and wool and furs are useful as heat preservers because they keep still air entangled. Human beings can moreover create a zone of stagnant air around their bodies by surrounding it with at least two layers of clothing. In countries where the people know that it is cold in winter, all houses, following the same principle, have two sets of window-panes. Similarly, polar travellers build their tents out of two thin layers of fabric separated by six inches of air.

Woollen garments are good enough as long as the air is still, but they do not protect against wind. For this

purpose, long staple cotton fabric of dense weave is recommended as ideal [redacted] it is almost impervious to wind and still allows the vapour of perspiration to pass out. Sleeping bags are made of eiderdown which [redacted] an even poorer conductor of heat than air.

Clothing must be kept absolutely dry. Damp cloth conducts heat and, besides, every particle of water or sweat turns immediately to ice. It [redacted] hair-raising to read what polar travellers hardly 30 years ago suffered from their sleeping bags clogged with ice, garments stiff like sheets of armour plate, frozen boots into which to squeeze one's feet was an hour's ordeal. The explorer of to-day leads a comparatively comfortable life, even without luxurious huts, in his double-walled tent which stands firm against wind, with the high pressure Primus stove drying all the clothing overnight and with restful sleep provided by the bulky eiderdown, where mouth and nose lie at the bottom of a deep fold, so that the breath has a long way to go before it freezes outside the bag.

As regards *Feeding*, the chief problems are not set at the base where there may be ample supplies, but on sledging parties where every ounce counts, and the ration must be computed in such a way that the intake of energy just balances the output. A measure for the efficiency of the party is the number of calories carried along per pound of total sledge load The hauling capacity of a nine-dog team [redacted] 900 pounds. Food for 2 men and 9 dogs amounts to 550 pounds for a month, fuel and camping equipment to 350 pounds. So thirty days' travel are safe—if nothing happens.

A comparison between the daily rations of 1875 with the present ones, as given by Dr. Bertram, is interesting.

1875	*Now*
16 oz. Pemmican	7 oz. Pemmican
4 oz Bacon	6 oz. Margarine
14 oz. Biscuits	3 oz. Biscuits
2 oz. Potatoes	2 oz. Pea Flour
2½ oz. Sugar	3 oz. Sugar

1875	*Now*
1 oz. Chocolate	3 oz. Oatmeal
½ oz Tea	3 oz. Chocolate
½ oz Salt, Pepper, Onions Curry Powder	1 oz. Cocoa
	3 oz. Milk Derivatives Vitamin Extracts
Total 41 ounces	Total 32 ounces

Pemmican is dried lean beef plus pure fat, spices and dried vegetables. Dogs get also one pound of it daily, of slightly different constitution Cocoa is taken with every meal, not tea as it has no food value. All indigestible matter is excluded

People can live for long periods on meat alone, therefore the sledger must become as carnivorous as possible. Fat provides twice as much energy as an equal weight of proteins or carbohydrates, but proteins are needed to build up new tissue, and *carbohydrates for muscular activity*. Therefore in cold climates the ratio of Protein: Fat : Carbohydrates should be 1 : 2 : 4, which, translated into calories, means 1 : 4 : 4.

Protein cannot be stored in the human body but is immediately burnt up and also stimulates the combustion of other food stuff. Fat can be stored; however it is stored at the wrong places, as Dr. Bertram remarks, not on the feet and hands where it is needed most

Transport

The instructions for the latest U.S Antarctic expedition state that although special equipment has been developed during the war and is now available, the primitive dog-drawn Eskimo sledge and team of husky-dogs is still indispensable The oldest and the newest forms of transport must work conjointly. Aeroplanes have crashed in crevasses, motor sledges have refused to work, and again and again dog teams have been the travellers' mainstay. Rymill's

party procured a stock of genuine Eskimo dogs and the offspring, natives of Antarctica, with crevices and crevasses as the scene of their first perambulations, proved to be excellent pullers at the age of eleven months Experience has taught that it is good to include bitches despite their inferior pulling power—even to use them as leaders because their presence enlivens the dogs

The carnivorous habits of dogs make them preferable to vegetarian animals such as horses or reindeer, because not only does their ordinary food take less space, but in extraordinary circumstances they can feed happily on their ex-colleagues

Near the coast a peculiar problem is set by the long periods in which travelling is impossible by sledge because the ice is unsafe and by boat because there is too much ice. Returning sledge parties are always anxious whether the sea ice will allow them to cross Perhaps the U S Navy which is now using Antarctica as manoeuvre grounds will invent a new amphibian for use on ice and in water

About the Reading of Polar Maps

If we want to scan an antarctic map, with the South Pole neatly in the centre, we must get rid of some inveterate habits of thought. We must not expect that the top of the map will show us what is north and the bottom what is south. We must accept, hard as it is, that, wherever we go, away from the South Pole, is north. North all round.

Just as puzzling is the west-east problem. We must realise that the Greenwich zero meridian signifies on the other side of the earth 180 degrees and is the line where 180 west and 180 east meet. Everything that lies between zero and 180 west is in the western hemisphere, but what would you call more, and what less westerly?

If we look at the map, unconsciously applying our customary standards, we should judge that the "East Base" of the Byrdians in Marguerite Bay is 100 degrees further west than their "West Base" on the Ross Shelf Ice. Now

the East Base is only 68° W and the West Base 164° W. Arithmetically it is indisputable that 164 is "more west" than 68. On this counting the western direction goes to the left as far as 90 degrees, then turns round and goes on to to the right.

However, the West Base with its 164° is only 16 degrees distant from the eastern hemisphere, i.e. 52 degrees nearer to the east or "more east" than the so-called East Base.

Further, in dealing with the pole we must keep in mind the different character of meridians and parallels. Meridians are the lines which connect the north pole with the south pole. They are all great circles and all equal. One degree of latitude, that is the 360th part of their circumference, has everywhere the same length. Not so the parallels. They shrink from the equator to the pole, and while one degree of longitude covers 69 miles on the equator, it covers only 12 miles at a latitude of 80 degrees. That is why polar travellers can manipulate longitude differences which may seem to us fantastic.

Polar explorers have often made much greater mistakes in ascertaining their longitude than their latitude. The unreliability of chronometers at very low temperatures is said to account for this weakness. Cannot the extreme smallness of the degrees also have something to do with it?

3. SCIENTIFIC RESULTS

Antarctica versus Arctica

Geography teaches that the polar zones are separated from the temperate zones by the Polar Circles in latitude 66° 33′ north and south, these being the lines beyond which during the summer the sun never disappears. There is a fundamental contrast between the North Pole and the South Pole. Not as a certain professor of philosophy imagined when he addressed his students with rhetorical pathos: "Whether you are shivering in the biting frost of

the ice-bound north pole, or suffocating in the torrid heat of the south pole . . .". No, not that. But there *is* a contrast between the two poles.

From the equator upwards to the north the continental mass broadens and has its greatest extension in medium latitudes, then the land recedes. The north pole is surrounded by water and is at sea level. From the equator downwards to the south, the land masses get narrower everywhere, but while between 35° and 65° S water prevails, we find beyond this latitude the vast Antarctic Continent with its six million square miles, bigger than the United States, bigger than Europe or Australia. The South Pole is embedded in this continent, lying on a plateau almost 10,000 feet in height.

The Arctic has a comparatively warm summer and as the lands around the polar sea are continuous with those of the temperate zone, they contain a rich flora and fauna including such land animals as the reindeer, the polar bear and the musk ox. In the Antarctic the temperature even in summer rises seldom above freezing (=melting) point. If the traveller exceptionally sees a green carpet, it consists of mosses and lichens. The even rarer occasions when he hits on a few specimens of a flowering plant assume almost festive character. The biggest land animal compares poorly with the musk ox, as its length is five millimetres. It is a wingless gnat.

The Antarctic waters, however, are in contact with the temperate zone and the sea animals can go north whenever it suits them. The waters teem with life, from microscopic crustaceans and rotifers up to whales of 100 feet length. Whereas in other continents, the continental shelf is only about 100 fathoms deep, the Antarctic mountains fall down to 1,000 fathoms. Warm waters emerge from the depth rich in mineral salts all around the continent. This together with the long daylight produces a rich concentration of plankton. For the temperate zone the close contact with the polar regions is not altogether plea-

as pack ice and ice-bergs, (of which one was 300 miles in length) penetrate far into the north, and cold bottom currents reach in some places as far as the equator.

At the surface the antarctic and sub-antarctic waters meet along a sharp boundary called the "Antarctic Convergence" which was discovered by Meinardus in 1923 and extensively studied since by the Discovery Committee. Its position is nearly half-way between the antarctic and the other continents, roughly at 60° S, just outside the pack ice limit It seems to go all round the continent, but has a tortuous contour including twists and loops.

The Convergence, not the Polar Circle, is biologically considered the boundary of Antarctica. Here the temperature of the surface water (down to 600 feet) changes abruptly, and certain species of micro-organisms and even of fishes cannot cross this barrier

Geography and Geology

The polar plateau appears as an ice cap of unknown thickness which descends outwards to the coasts. Still there is enough bare rock to satisfy the geologist. The solid mass of these mountains is igneous, partly volcanic, and one volcano, Mt Erebus on Ross Island, sends up to the sky a high cloud plume which serves as a weather vane.

Between the rocks of Graham Land and the South American Andes there is a striking similarity and an ancient land bridge is assumed between the two continents. Echo soundings have revealed extensive submarine connections between S America and Antarctica According to the Byrdian, Mr. Bryant, what little flora exists is evidence for land bridges, connecting Antarctica not only with South America but also with New Zealand.

The geographical discoveries of the Grahamers contain one chapter which is pathetic. In Griffith Taylor's instructive book *Antarctic Adventure and Research* (1930) we read that "December 20th, 1928, was the most wonderful day, for in ten hours Sir Hubert Wilkins settled more problems

and sketched more new coast-lines than any other expedition had accomplished."

His chief glory was the discovery of several straits running west and east across Graham Land, separating it from the continent. The main strait or sound which Wilkins called Stefansson Strait would have provided a splendid avenue to the south of the Weddell Sea which otherwise was almost inaccessible from the west. So Mr. Rymill's party based their plans on making use of Stefansson Strait. But what Wilkins looking down from the air had regarded as a strait was really a very high glacier valley not reachable from the coast. It cost one of the Grahamers, Mr. A. Stephensen, after his return to England a vast amount of labour to prove with overwhelming evidence that there is no Stefansson Strait and that Graham Land is indeed part of the main land as it was believed to be—until that wonderful day in December.

From this the lesson was drawn that a flier, especially over ice- or snow-covered country, is unable to determine *heights, and air reconnaissance without the help of some* known ground features is insufficient. Indeed, a very important real strait over 200 miles long and 15–20 miles wide which the Grahamers discovered was not sighted at all by Mr. Lincoln Ellsworth when he flew over the country.

This new strait called *King George VI Sound* is the major discovery of Rymill's party. On the shelf ice of this sound one can sledge without great difficulty, and it may open a route to the heart of the continent and to still unknown coastal areas to the west. Unfortunately the Grahamers, having wasted so much time on the Stefansson Strait, could not pursue their discovery to the end. They followed the sound down a long way until it turned west, but had to leave off without knowing how far west it went and whether it ended in high land or in the sea. The map shows the sound at this stage of uncertainty. The Byrdians who had carefully studied Mr Rymill's book carried on his work and established, that the sound opens to the west to a great

ice-free sea. Thus Alexander I Land, so named by the Russian Bellingshausen who discovered it in 1820, has now become Alexander I Island.

The channel is also of geological importance as it separates provinces of very different character. East of King George Sound is Graham Land with its bedrock, west of it runs the 8,000-foot mountain range of Alexander I Island which contains sediments carrying a rich assortment of fossils.

It would seem as if here and there, scattered over the continent, almost all types of fossils are represented—except reptiles and mammals. Some fossil plants indicate an ancient subtropical climate.

As to minerals, only low-grade coal has been found and isolated deposits of copper ores. Nor is there any definite evidence for oil-bearing layers.

The Weddell Sea and the Ross Sea

These two large bays are the only ones which cut deep into the otherwise massive bulk of the Antarctic Continent. The Weddell Sea is in the British, the Ross Sea in the New Zealand sector. They are both inhabited by that uncanny white monster, the Pack, which guards the coasts of the continent. If ships try to defy the monster, they soon feel gripped in its icy claws, kept prisoner indefinitely, kicked about, and not too rarely crushed to pieces—as happened to Shackleton's "Endurance" and to Nordenskjold's "Antarctic"

The Weddell Sea is of particular interest to oceanographers as the source of the antarctic bottom current. For some reason the cold shelf water in this bay—but nowhere else—sinks to the ocean bed and from there spreads, not only through the whole Southern Ocean but even northwards into all the other three (Atlantic, Pacific, Indian).

Now there is something almost magical in this Weddell Sea current, for the territories of S. Georgia, the S. Orkney

and Sandwich Islands are, under its influence, extremely rich in animals and plants compared with the territory west of them. "One would like to know", says an expert, "the history of the water which leaves the Weddell Sea, i.e., the water which enters it from the east." We shall see in the Biology paragraphs that the neighbourhood of the Weddell Sea seems favourable for reproduction.

The polar end of both bays is filled with *shelf ice*, a fascinating, awe-inspiring, tremendous mystery, a structure which has aroused more interest than any other glacial type. No colossal sheet of that kind is known in the north.

The Filchner Ice Shelf at the head of the Weddell Sea is completely unexplored, but the Ross Ice Shelf has been frequently surveyed. The Byrdians had their West Base right on the shelf ice and constructed a special Ice Laboratory on it. It is interesting that their leading scientist, Professor Alton Wade, consulted the British Glaciological Society about the experimental programme.

The Ross Shelf is a triangle whose seaward face runs nearly west and east and is about 400–500 miles long. As the shelf is in slow but constant movement, the measurements change. Its total area is roughly the size of France. Where the shelf bars the way, sailors called it a Barrier.

The characteristic of a shelf is that its seaward end floats freely on the water. When a ship is moored to the ice, it moves up and down with the tide in unison with the ice shelf. But the inner end is held fast to the continent by the glaciers which act as feeders, and by being aground close to the coast. Near the margin or where glaciers enter it, the sheet may be thrown into pressure waves some forty feet high and 1–2 miles from crest to crest. On aerial photographs the ice may then appear like jelly or junket. Otherwise the Ross Shelf surface is smooth, and as it reaches within 300 miles of the South Pole, it has always been chosen as the avenue to that spot.

A problem child of the Ross Sea is the *Bay of Wha'*

On the Argentine Islands (65°S) and also on an island further south, Dr Bertram found a very rich botanical display, consisting of a most remarkable sporadic occurrence of a closed moss association up to an acre in area. In places the moss formed a peat three feet thick, but except for a few inches at the surface which thawed up in summer it was permanently frozen.

In these places, one of the two flowering plants which the Antarctic can boast was also present. It is a relative of pinks and campions, called *Colobanthus crassifolius*. The other flowering plant is *Deschampsia antarctica*, a grass often seen scattered in small tufts. No flowering plants have yet been found anywhere on the continent outside Graham Land. The typical antarctic plants are the lichens. Three of their species occur also in South America and 25 in New Zealand.

Various tiny terrestrial insects live south of the Antarctic Circle. One Collembola species was found floating in a trickle of water below a snow bank and it seemed to emerge from an algae-covered crack in the rocks. Wherever there was a small water course, Collembola could be collected from it in swarms so thick that they looked like blotches of soot. When over night the water froze, Collembola was to be seen nowhere. Mites are much more frequent than insects.

Near the penguin rookeries rich vegetation develops, but one observer rejects the obvious inference that the bird manure is responsible for this.

Birds there are in plenty, gulls and terns and skuas, and the water contains a great variety of animals.

In the following paragraphs I give only a few data about those animals which have been specially studied recently, viz. seals, petrels and penguins.

Seals

The antarctic animals are not yet afraid of man. Birds as well as seals can be freely watched and easily killed.

Seals lie placidly on the beach awaiting the enemy and keep their serenity even when a few of their fellows have been put to death before their eyes.

Most antarctic seals are "True Seals" as distinguished from Eared Seals and Walruses. The most powerful among them is the Sea Elephant which is now kept under Government control in S. Georgia after an immense and wasteful slaughter had almost exterminated the species. The male sea elephant is bigger than his female and is polygamous. An interesting correlation has been noted between sex sizes and polygamy. Thus the northern Fur Seal which may be six times as big as the female, commands a harem of 40 to 70 cows fighting off all rivals. But in most antarctic seals the female is slightly bigger. The Sea Leopard, 12 ft. long, of snake-like appearance, does not live gregariously like the others and is a vicious predator. It eats little seals and penguins.

The Ross Seal, 7 ft. long, is very rare. Only a few were sighted in the Ross Sea.

The most common seals in West Antarctica are the Weddell Seal, 10 ft. long, and the Crabeater (8 ft.). Dr. Bertram, a Grahamer, in order to study them thoroughly, took upon himself the gruesome work of butchering almost all the 367 Weddell Seals and 177 Crabeaters which were required to feed men and dogs.

The Weddell Seals live mostly in the water and in winter below the ice. They use their sharp teeth to saw out breathing holes or enlarge existing cracks But this hard job soon wears their teeth out, and when they lose their teeth, they must perish These poor seals are very unhealthy creatures. They have nasty skin diseases, large festering sores, their wounds heal very slowly, their bowels are choked with worms of all kinds. Nor do they live long, not more than eight years probably.

Their age can, as with whales, be estimated from the number of "yellow bodies" in their ovaries. These are the follicles from which eggs are formed and which in the

Weddell Seal persist unto death. As a seal develops only one egg a year, the number of yellow bodies in the females gives an indication as to their age.

Copulation has never been seen and obviously occurs in the water. In spring (September) the cows come out on the beaches and give birth to one pup each.

The pregnancy lasts very long, ten months, and when the pup appears, it is almost ready for an independent life. It weighs 60 lb and gains 7 each day by suckling. It is born with a thick woolly coat which it soon exchanges for the hair of the adult. Then it goes into the water and is rarely seen again until it is sexually mature.

This stage is reached in the Antarctic a year earlier than in the north Weddell Seals become pregnant at 26 months, Crabeaters even at 15 months

Weddell Seals live on fish and cephalopods, Crabeaters on a shrimp-like Crustacean known as Krill which is present in such immense quantities as to satisfy even the appetite of giant whales.

Crabeaters do not show traces in their teeth of sawing, though they too live below the ice. They have no diseases, no worms, and while there is hardly one which does not carry on its body enormous parallel scars inflicted by the teeth of the Killer Whale, even this does not seem to disturb their health

Antarctic seals can sing. They command a whole octave of musical notes and it takes authors many lines to describe the variety of their utterances.

When a seal is wounded or otherwise senses its approaching death, it retires as far as thirty miles into the interior or on a mountain 2,000 feet high, there to die in solitude and dignity.

Petrels and Penguins

When we hear that birds leave our inhospitable north *in the autumn to spend their winter in the south, the last* place where we should expect them to go is the neighbour-

hood of the south pole. Yet Wilson's Petrel, a bird which is seen in the Persian Gulf, in Peru and in the Red Sea, has got it into his head that he cannot breed anywhere else than in Antarctica. Dr. Brian Roberts, of the Grahamers, was fortunate enough to have a nesting colony of these birds in a small moss patch on the Argentine Islands and could watch their courtship and breeding habits—their flying around the island every evening for a week without going ashore, their flitting up and down and around the colony, occasionally alighting, for another week, until at last they settled down. As was revealed by the rings attached to their feet, each bird moved into his "old digs" together with his old mate Dr. Roberts thinks it is the common accommodation which keeps the couples together, rather than love. One can find several subsequent residences, one on top of the other, as in some excavated Oriental cities When the egg is laid, only one every year, each parent sits on it for 48 hours in rigid rhythm, and if a scientist kidnaps a sitting bird, the egg is left alone until the time appointed for the changeover. It does not seem to hurt the egg In April, at the end of the southern summer, the petrels go north where they successfully escape scientific observation

Petrels live in general on Krill, but they are also fond of oil and assemble in huge flocks round floating whale factories, feeding on scattered oil drops Their habit of ejecting oil has been shrewdly utilised in some places: if a wick is drawn through their mouth and anus, it serves as a candle.

Neither in petrels nor in penguins is there any sex distinction during the courtship, and the aim of all display is, according to Dr. Roberts, definitely not to woo and select a mate. The breeding cycle of all higher organisms, including such activities as nest building, is regulated by *hormones and the glands which supply them. But the* glands in their turn respond to stimuli and these include season and climate as well as the appearance and behaviour of the other partner. "The pair which has the greatest

capacity for mutual stimulation will be the most successful in perpetuating the race."

Birds themselves cannot distinguish sex visually. They can only find out by trial and error. They call and see what response they get. That is apparently why they call so much In penguins large-scale ringing had not yet been performed, so Roberts could do nothing but watch the birds' behaviour first and then ascertain their sex by a post-mortem. Before copulation both sexes behave as males. It looks as if the female characters were developed later only.

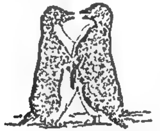


Fig 2 —Fighting

The breeding period is introduced by much crowing. The penguins sort themselves out in pairs and these call

Fig 3.—Bowing.

and bow to each other. They are strongly addicted to ceremonious bowing, and the high-light of the photos taken is the picture of a bird who, with a deep and respectful bow, lays a pebble at the feet of his beloved. Pebbles are not just jewellery, they are used for nest building, and also swallowed by penguins as well as seals. Whether they help to grind the food is not yet clear.

Fig 4.—Copulation

In the pre-laying period penguins often assume an "ecstatic attitude", neck elongated, bill raised to heaven, flippers beating in a slow rhythm, accompanied by braying or trumpeting. If one bird starts the display, all the others soon join in.

Penguins have a passion for brooding out something, preferably an egg, but a lump of dirty ice may also do. Hatching is done in turns, and there is a special "nest *relief ceremony*", for if the relief approaches the nest without hissing the pass word and bowing elaborately, it is attacked.

Fig 5.—Nest-relief ceremony

Sometimes penguins will strike attitudes, pick up and deposit pebbles when they are alone, or prepare a nest and leave it unoccupied. Such apparently aimless behaviour seems one more illustration of the theory that most games of young animals are a preparation for the earnest of life.

While the parents go out to get food, all the young of a rookery are assembled in crèches with a pair of adults to keep them together These nurses, however, did not budge when an enemy attacked and disembowelled some of the chicks

In general, penguins lay their eggs in spring or summer, only the Emperor Penguins lay theirs in midwinter, and it is a heroic story worth recounting that the worst part of "The Worst Journey in the World"—five weeks in utter darkness at a temperature between 60 and 77 degrees below zero in a blizzard which blew the tent away—was undertaken by three martyrs of science, Wilson, Bowers, and Cherry-Garrard, for no other purpose than to secure some of these eggs Why? Because the Emperor *Penguin* is the most primitive of all penguins, and the idea was, in accordance with the evolutionary notions prevailing at that time, to find in the embyro "the missing link between birds and reptiles". Unfortunately, none of the eggs they brought back to England contained an embryo

Austere and dangerous as the explorer's life may be, it has its peculiar reward—not only the satisfaction of the sportsman and of the scientist, but deeper spiritual joy. Shackleton wrote· "*When I look back at those days,* I have no doubt that Providence guided us. I know that during that long and racking march it seemed to me often that we were four, not three. I said nothing to my companions, but afterwards Wordsley said to me: 'Boss, I had a curious feeling on the march that there was another person with us.' Crean confessed to the same idea. A record of our journeys would be incomplete without reference to a subject which is very near our hearts."

Colin Bertram quoting these words adds that to most

travellers in the empty places of the earth is given something of the feelings of mystics and hermits and a re-adjustment of relative values, and that they may find a deeper and wider meaning in the Scott epitaph on the Polar Research Institute

QUAESIVIT ARCANA POLI VIDET DEI

It might to them mean: He who has searched for the *mysteries of the pole, sees the mystery of God.*

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Making Penicillin

BY DR. E. LESTER SMITH AND J. L. CRAMMER

THERE *are three historic occasions in the story of Penicillin* The first was its discovery by Fleming in 1929; the second, 1932, a report on its chemical properties by Raistrick; and the third and most exciting, the announcement of its great medical importance by Florey in 1940. His Oxford group of scientists had found out how to make the drug sufficiently pure to treat human sickness, though the quantities available were enough only for one or two cases.

The publicised story usually stops at this point as though the whole work were then done. In fact, however, it was only the beginning of a vast cooperative effort to find out how to make the drug on a factory scale. Its production in the laboratory by skilled chemists working at their own speed with straggling glass apparatus could be little guide to mass production by unskilled labour. In the factory we are faced with the effort to make the maximum quantity of pure penicillin in the minimum possible time, we have to think of the cost, of the space required to make it in, of fool-proofing the processes, of guiding and checking them, and of employing the available factories and labour as efficiently as possible by making the purification production process continuous. This involved much research in botany, chemistry, chemical engineering, and bacteriology, as we shall shortly see. There was an added complication, which affected the whole development of the processes: Britain was at war, and materials and labour were in short supply.

The essence of making penicillin is simple. A mould, *Penicillium notatum*, is grown on a watery solution containing various salts and sugar. As it grows it forms small amounts of penicillin which it excretes into the water.

Eventually, the mould is skimmed or filtered off and thrown away, and the penicillin extracted from the fluid on which it formerly grew. There are several ways of extraction and the most important depends on the fact that penicillin is an acid substance which can be pushed about from water into chloroform (for instance) and back again by altering the acidity or alkalinity of the water layer. For it must be remembered that there are a very large number of liquids which do not mix appreciably with water, but float on its surface like oil, or rest heavily beneath it, when the two are placed together in a tank.

Such, for instance, are ether, chloroform, amyl alcohol and acetate, which will all dissolve penicillin quite readily, provided it is present as an acid, and not as a salt. So the culture medium is made acid and shaken with amyl acetate and the penicillin passes into the amyl acetate layer, leaving the salts and many impurities behind

The amyl acetate is then separated off, and shaken with clean water, which has been made a little alkaline. Now the penicillin passes back into the water again The water is drawn off, made acid, and shaken with chloroform which now picks up the penicillin in its turn, to yield it again to fresh alkaline water, for instance containing lime, so that the calcium salt of penicillin is prepared ready for use

This all sounds simple enough to anyone who knows a little chemistry. It is basically how the Oxford workers made the first specimens of penicillin Where are the snags? Let us go back and view the process in more detail, and they will quickly emerge.

The Horticultural Problem

Penicillium is a living plant, and the first step is to grow it. In ordinary gardening the aim is to get the biggest marrows, the juiciest and reddest tomatoes; in this special form of horticulture, however, the goal is quite different. We do not care for the plant at all: we are after a particular substance rather easily damaged, which the plant happens

apparently accidentally to excrete into the soil in small quantities. Penicillin is not the only, or even the chief substance, that it excretes. In the early experiments, the medium at the best contained about 10 units penicillin per ml. (equivalent to six millionths of a gramme of pure sodium penicillin II), and a single patient requires 100,000 units every three or four hours, often for several days. The first big research problem was thus how to make the plant produce the maximum of penicillin, and it was soon found best to grow it at 24°C, for about seven to eleven days before harvesting. for the penicillin produced increases slowly as the plant grows, and then after a time is slowly destroyed again by further growth, so that the maturing cultures must be carefully watched. As the plant grows it consumes a great deal of oxygen and exhales much carbon dioxide, so that gases must be allowed free entry and exit to the plant. As it grows, too, it produces warmth, like the heat of fermenting grass in a manure pile, so the circulating air must distribute this heat, or carry it away, if the temperature is to be kept at the desirable 24°C.

When this was settled the question of the best "soil" and the best "manure" became important. At the start every one used a synthetic medium—a mixture of phosphates, sulphates, chlorides and nitrates of sodium, potassium, magnesium, and iron together with 4 per cent of sugar (glucose) all dissolved in water. This Czapek-Dox medium, as it is called, is a stock one in the laboratory for growing moulds of all kinds for research purposes, and is similar to the solutions for water culture of green plants, as in hydroponics. It did not always give very good results, and it was found that the mould needed also traces of copper and zinc, not supplied in the Czapek-Dox mixture, but obtained haphazard from the glass of the growth tank, or from impurities in the water. Many experiments were tried with different foods for the mould, until finally the Americans hit on a really good medium, which was not synthetic but conveniently the by-product from another

industry. In the manufacture of starch, maize is steeped in warm water; various substances are soaked out and undergo a certain amount of bacterial fermentation. Originally this corn steep liquor had to be thrown away. After the addition of lactose (milk sugar), however, it was found to be ideal for growing *Penicillium notatum*, and using it one can get over 200 units of penicillin per ml., a twentyfold improvement on the starting position. What makes corn steep liquor so good seems to be a whole mixture of substances present, and so it is better to use the natural brown syrupy liquor than try for a synthetic substitute.

One further bright idea came out when the chemical structure of penicillin was finally solved. It was thought that it might be possible to provide some of the actual materials which the mould uses in building up the drug molecule, and so save it the labour of making these building bricks first, as it grew, and thus speed up production. Chemicals were found which would actually do this, but they are still on the secret list.

Another aspect of the botanical problem altogether was the question of the best "seed". Just as there are many different varieties of potatoes and roses, so there are many strains of *penicillium notatum*, which vary in their penicillin-producing power. A wide search was conducted through all the known laboratory-civilised strains, fresh wild strains were isolated from soils in various places, and a new line of research sprang up and is still very actively under way. When a mould gets a dose of X-rays, or ultra-violet light, or treatment with certain special chemicals, such as mustard gas, its chromosomes are affected, and consequently its inheritance altered so that its "seeds" or spores will grow into young moulds differing in a haphazard variety of ways from their parents These mutations, as they are called, are then studied one by one for biological differences, such as better penicillin production, speedier growth, and so on, in the hopes that one day the perfect mould wi

turn up, which will spend its whole time and energy penicillin making.

What about "weeds"? These turn out to be particularly menacing in the *Penicillium* garden. Many bacteria produce an enzyme or digestive ferment called penicillinase which smashes penicillin up in no time. Therefore all the culture fluids have to be carefully sterilised, all the culture vessels likewise, the seeds have to be sown aseptically, the air must be bacteria-free—in all the early stages a sharp look-out must be kept for "weeds". In the early days, when the mould was grown in hundreds and thousands of milk bottles,* and the contents later pooled, pencillinase from one weedy bottle might ruin the whole lot, and the weeds might be invisible at that. It was very necessary to train and supervise the ordinary unskilled labour available in the proper aseptic techniques for plugging the sterile bottles with sterile cotton wool and so on, to avoid this very unwelcome penicillinase production. Each sterile milk bottle had later to be momentarily unplugged and inoculated with penicillium spores, and here again was a dangerous manoeuvre. The spores were usually suspended in a little sterile water and sprayed or shot in from a pipette delivering constant volumes, and this required specially trained operators.

The production of the spores from the chosen strain of mould in itself is an important job needing a special department of the factory. The strain has to be kept pure, free from foreign moulds and bacteria, and unchanging in its growth and habits. With continued subculture there is always the danger that a natural mutation may occur, or the mould drift into another way of living, just as disease bacteria grown for generations on laboratory media lose their virulence and become mild.

* Milk bottles were chosen in wartime as being easily available; and the big dairies had already worked out how to handle them in bulk on a moving belt for washing, sterilising, filling, etc. One pharmaceutical company alone acquired three quarters of a million of them.

The Engineering Problem

While botanical research, or more precisely, microbiological experiments, defined the sort of conditions required, the engineers were busy supplying those conditions on a mass scale. Since the mould would only grow on the surface of the culture medium, where there was plenty of air, it was necessary to get a large fluid surface, and at first this was obtained by putting the medium in thousands of milk bottles lying on their sides, 10° from the full horizontal so that the cotton-wool plugs were not wetted. Amongst several drawbacks one important one was the varying depth of liquid in such a bottle, leading to non-uniform growth, and waste

Glaxo therefore designed and used special glass vessels shaped rather like sealed saucepans with an entrance through a hollow handle (Plate 13). These could be easily stacked and handled and contained a uniform depth of culture fluid. Test showed that the "handle" entrance was big enough for free circulation of gases; but the shape was very awkward for washing, and the vessels expensive to make

There were other approaches to the growth problem. Some firms tried growing the mould in shallow trays. Although apparently simple, this too had snags the trays had to be fairly small, rigid, and carefully levelled, each filled with the right amount of medium, aseptically inoculated with spores, and incubated for a week or so in a current of sterile air. It was possible to arrange the trays in banks, so that sterile medium flowed in at the top and slowly overflowed from one tray to the next, emerging rich in penicillin at the bottom—but in practice this was difficult. Another method was to grow the mould on moist bran A third was modelled on vinegar manufacture. Sterile medium flows slowly down towers packed with some inert sterile support inoculated with mould spores. After a time the outflowing liquid contains penicillin, and output is continuous until the tower chokes with mould, or gets infected by penicillinase-making bacteria.

From the beginning there was always the dream that the mould might be persuaded to grow submerged and scattered throughout a large tank of medium, but early trials were very discouraging. It seemed the mould would only grow on the surface However, the Americans persevered, and after spending millions of dollars were able finally to announce success. In fact the deep tank submerged culture method of penicillin manufacture has now become the standard method in industrial production in both the United States and Britain. Tanks containing 5,000—10,000 gallons are commonly used and growth takes only a few days: one tank of this sort produces penicillin at the same rate as half a million milk bottles (Plate 15).

The basic engineering problem which was so difficult to solve, was how to keep a tankful of medium, through which plenty of sterile air had to be blown and the liquid well stirred, completely free of bacterial contamination for several days. Its solution demanded the invention of many ingenious devices which are closely guarded industrial secrets. There were also subsidiary problems. One was what to make the tanks out of Early research suggested that even traces of most metals would rapidly destroy penicillin, but fortunately stainless steel was found to be harmless and therefore very suitable The change from surface to deep culture meant that other strains of *penicillium notatum* would now grow better, and changes in the chemical composition of the culture medium became necessary. This in turn rebounded on the rest of the factory, which also had to be modified. As just one example of how improvement in one part of a process upsets the rest, requiring yet more research and development to set it right, we may mention that in the early days the first treatment of the culture medium after growth was with charcoal, which adsorbed the penicillin from solution: later the penicillin could be got back into a small amount of clean liquid, thus purified and concentrated. When however, corn steep liquor came into use as culture medium,

the charcoal process would no longer work advantageously, and had to be abandoned.

Today, after the growth of mould has been filtered off (see Plate 16), the fluid is acidified and extracted with amyl acetate; the two solvents are well mixed together and then *quickly separated again in a centrifuge which spins them* apart (see Plate 17). The centrifuge, incidentally, is an instrument already important industrially in oil refining for separating oil from water with which it has been washed, so that this part of the penicillin process has required adaptation rather than invention. The concentration and purification of penicillin then proceeds on the lines already briefly sketched, passing it back and forth between pairs of solvents. The secrets of the process lie in the accurate adjustment of the precise acidity or alkalinity of the water each time This is vital for two reasons. One is that penicillin is unstable and begins to decompose if its solution gets far from neutrality on either acid or alkaline side, so that a process involving such changes is risky and needs very careful control The other reason is that the degree of purity achieved depends on it When penicillin passes from water into amyl acetate, so to a certain extent do some other substances present in the culture medium, either unused components of the corn steep liquor, or other products excreted by the mould. The precise degree to which these impurities pass over from solvent to solvent each time also depends on the acidity, though the best conditions are not identical with the best conditions for penicillin stability. Therefore, by very careful adjustment, it is possible each time to leave a very large proportion of the impurities behind, and so to get purer and purer penicillin, though a small proportion of the penicillin has to be sacrificed at each stage.

This will yield penicillin from about 30 per cent to 80 per cent pure, which is good enough for ordinary medical purposes 100 per cent pure white crystalline penicillin is also available for special cases such as brain surger

it is much more expensive, because the extra refining, involving recrystallisation of penicillin as the salt of an organic base, is a skilled business (Plate 21)

Penicillin keeps best in the dry state, and the final stage in its processing is to dry it (see Plates 19 and 20). It was found best to put the right amount of 10 per cent solution into each vial or ampoule and then dry it by freezing the solution quickly with solid carbon dioxide to —30°C and applying a high vacuum to "suck off" the frozen water This process of freeze-drying is very suitable for unstable substances like penicillin It has been much used also in preparing dried blood plasma (another fragile stuff), stored thus for transfusions. The secret of success is to have exactly the right conditions—and finding them was a great deal of work. A really good vacuum (about 0.02 mm mercury) is essential, and so is a good condenser (at about —50°C) to trap and solidify the ice-vapour in another part of the system. When completely dry, the ampoules are sealed off, labelled, packed: the drug is ready for use

Laboratory Studies

Naturally a great deal of work has been done to find out what destroys penicillin and what preserves it. Some of the destructive agencies—penicillinase, metal ions, acidity, heat, have already been mentioned A sharp look out must be kept for them during manufacture, and in addition the amount of penicillin present in the culture fluid at harvesting of the mould, and the amount present in solution at the end of processing before drying, must be assayed as a *matter of routine. From such a practice* we learn that under present conditions about 40 cent of the penicillin is lost during manufacture, nevertheless, this is commercially good enough. The solution is filtered through a Seitz filter before drying to remove bacteria. Batches of the dried product are also tested in the bacteriological laboratory to make sure they are in fact free of

germs.* Some of the batch is injected into rabbits to make sure it is free of the mysterious impurities which will cause sudden rises of temperature and rigors when injected. A further sample is injected into mice to be certain that it is non-poisonous.

Clearly all these tests require trained scientific workers. Clearly also, the running of such an industry, and the solution of the multifarious problems that arise needs chemical engineers, biologists, chemists. The production of streptomycin, the only other antibiotic of industrial interest at present, is much less developed, and offers many similar problems to be tackled. It is partly out of the recognition of the growing importance of the whole field that the University of Cambridge has this year for the first time instituted a special advanced twelve months' course in chemical microbiology.

The growing importance of the penicillin industry itself is shown by the following figures They give the average monthly output in millions of units:

	U S.A	*Britain*
1943	1,700	300
1944	138,000	3,200
1945	570,000	26,000
1946	800,000	260,000
1947	1,000,000	400,000

They are a measure of the success achieved in the largest (non-military) scientific combined operation hitherto undertaken by mankind, and a stimulus and guide to future effort.

* To make such a test, the penicillin in the sample is first destroyed with penicillinase, and then the sample placed on the usual broths, blood agar medium, etc, on which any bacterial growth can occur Any germ present will thus reveal itself

Farming Front

BY R. N. HIGINBOTHAM

The N.A.A.S.

AT the beginning of July last, the farming community had the pleasure of reading about or attending the first Royal Show since before the war, and the differences between Windsor (1939) and Lincoln (1947) were much remarked upon. In particular, exhibits designed by the various advisory services available to agriculture were on a larger scale than ever before. The main organisation concerned in this was the newly-founded National Agricultural Advisory Service, which is now the chief instrument of scientific popularisation for the industry Such organisations as the Milk Marketing Board and the Department of Scientific and Industrial Research, which, together with commercial firms and producers' societies, provide a great deal of useful information, were also represented But there is a difference between them and the N.A.A.S , which is the only body giving advice on the whole of agriculture to all producers in all parts of the country. As such it has been specifically designed by the Government, as part of the new national land policy, out of the previous regional advisory services with their local colleges, and it includes various research institutes. It is to be developed into a standard service employing people of a more or less standard ability and knowledge in its various grades, and so supplying a product, advice, which will not vary very much from one area to another. It is claimed that within this comprehensive service knowledge will be diffused more quickly than between the old separate groups; new research will get known more quickly and already existing specialised knowledge will be more easily integrated on to any par-

ticular farming problem; in addition, there will be refresher courses for Advisory Officers and so on.

Success in these objects is a matter of administration and that is why the Service's success at the Royal is encouraging. But it is also a matter of psychological understanding, and, here again, what its spokesmen have to say is encouraging. So far they have avoided pronouncements which would make one think they had underrated the difficulty of popularising scientific knowledge among farmers The emphasis has been on working "with" the farmer, not "for" him, still less against him. All experience of agricultural educational work shows that this is the only possible approach: you have to get the farmer mixed up in your ideas or he will not absorb them; otherwise, though the problem he has raised may have been solved theoretically, it will not have been solved practically. In fact, also, the Service itself will need the cooperation of farmers It will have many new ideas to develop and they will require testing out in the ground. It will maintain experimental farms of its own, but it can never hope to cover a sufficiently wide ecological range for its "pilot plant" experiments without the cooperation of the farming community. In so far as the Advisory Officer is an experimenter and investigator, therefore, he will need to work with the local farmers; and where he is an innovator he will need to learn from them the effect of his novelties on farm management and economics.

No farmer can know enough, without advice, to get the full benefits of the application of modern scientific knowledge to his land, and it is to be hoped that enough of them will admit the fact to allow the new Service to develop its full impact upon our productivity and their profits. It is a free gift, indeed, to farmers, it is all honey. Naturally there is a sting; something will be expected in return. There are many other advisory services available to farmers in many other countries, but the significance of this British edition is, as has been said above, that it is part of

national land policy. This policy provides for the expropriation of inefficient producers. In practice this will mean farmers of unjustifiably low productivity compared with the average. The declared object of the N.A.A.S. is to raise the average of productivity. So it will not do to get too far behind one's neighbours in the application of science to one's farming.

Scientists connected with agriculture, on the other hand, will find this large organisation less interested in the answers to some questions than in others and more likely to employ certain types of scientist than others. Practical need will determine the questions it asks and practical ability will be necessary in its employees. It is possible that in the long run agricultural science will be pretty well absorbed by the N.A.A.S., though that is nobody's intention at the moment. Or, to put the thing less controversially, agricultural research will be guided along certain directed lines in response to practical demand. Professor Scott Watson, Chief Education and Advisory Officer at the Ministry of Agriculture and head of the new service, gave, last January, "a random sample of the various fields of research" to "indicate what progress is being made and what gaps in our knowledge remain to be filled" to a conference in Edinburgh. Three items in his sample, trace elements, plant hormone synthesis and new varieties of potato, have already been talked about in *Science News* 3. It may be interesting to follow up issues related to some of his other items to illustrate his theme of "progress" and "gaps."

Fertiliser Placement

The seed of most crops is sown through drills, which deposit it in rows, whereas fertilisers are usually, in English practice, applied to the seed-bed through distributors which give an even covering over the whole ground. Apparently, therefore, much of the fertiliser is applied where, from the point of view of that immediate crop, it is not wanted, between the rows, particularly with crops which are sown

in wide rows, such as potatoes and sugar beet This waste of fertiliser could possibly be avoided by depositing the fertiliser in bands close to the roots. There is another economy concerned here too. When calcium or nitrogen is applied to the soil, almost the whole of it is available for solution in the soil water and thus for absorption by the roots of plants. But a large proportion of any phosphate applied is transformed in the soil to compound forms insoluble in water, and is thus locked up and only becomes available for plant nutrition over a long period and partially. (That is, you can never hope to get back from the soil anything like as much phosphate as you have to apply to it.) Now this locking-up effect is reduced if the phosphatic fertiliser is not mixed generally with the soil, but is placed in narrow bands. Since phosphatic fertilisers are the great necessity for high yields in most British soils, this is important.

From a rather different angle farmers and manufacturers, aiming at the economy of a single operation in tead of two, have for many years experimented with combined drills, capable of putting down the seed and the fertiliser in the one drilling. Such machines have been known in this country for at least a century and probably more. They were never satisfactory and an easier line of progress was found in the perfecting of the general distributor, after which interest in combined drills waned. Since the last war, however, the question has been taken up again. Manufacturers have made available combined drills capable of putting the fertiliser down with the seed Scientists have asked themselves whether these bands of fertiliser are really best located in contact with the seed or a little away from it, and, if the latter, just where. Engineers have wondered how.

Engineers first. It is not so hard to arrange for fertiliser to be deposited with the seed, though there are tiresome problems, such as the corrosive effect of many fertilisers on mechanism and the varying physical condition in which

national land policy. This policy provides for the expropriation of inefficient producers. In practice this will mean farmers of unjustifiably low productivity compared with the average. The declared object of the N.A.A.S. is to raise the average of productivity. So it will not do to get too far behind one's neighbours in the application of science to one's farming.

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they end up after a short trip on the British railways and a few months' farm storage But research into fertiliser placement implies machinery capable of depositing *accurate amounts independent of external factors.* Commercial drills are gravity-feeding, assisted by some sort of mechanism to keep the fertiliser running through: essentially they shake the stuff out Their delivery rates, for various settings of the mechanism, will vary greatly according to the "condition" of the particular batch of fertiliser in question. You cannot get much further here because the "condition" of a finely powdered or even a granulated fertiliser is difficult to define in a useful way, it may be anything from the fine powder it was sent out as (rare) to a collection of different sized lumps. The rates vary according to humidity, but no relation can be established between the rates and the humidities. Gravity feeds, therefore, are no use for research into fertiliser placement: which prompts the reflection that eventually they will be rejected for commercial work, since the whole essence of this problem is accuracy of delivery, both in quantity and location. For research, the only reliable method of feed is by positive displacement. Here a piston rises in a cylinder filled with the fertiliser, which is then deflected down the feed tubes by scrapers. Thus the same *volume* of fertiliser is delivered each time. The *weight* delivered is slightly variable, because of differences of density in the fertiliser caused by being jolted over rough ground, by the vibration of the tractor, by compaction by the piston and, again, to a small extent by the condition of the fertiliser. The variability can be much reduced by running the machine for a bit before starting on the measured work, so that the fertiliser can settle down.

Thus, as so often in agricultural research, an immense amount of mechanical playing about has to be gone through before the investigation can really start. After that, there are really two questions

(a) is there a significant variation in yield proportionate

to quantity of fertiliser used, according to whether it is generally distributed or is placed in bands?

(b) assuming that fertiliser should be placed in bands, what is the best position for those bands?

It is confirmed that, for *cereal* crops, phosphates sown down a combined drill in contact with the seed are about as effective as twice the quantity distributed generally, in average cases; and in phosphate-deficient land, considerably more so. Up to quite large quantities of phosphates and compound manures can be combined safely, without damage to the germinating power of the seed, which fixes the upper limit of the method. Less definite results have emerged from experiments with potassium and nitrogenous fertilisers. But *root-crop seeds*, excepting potatoes, very easily suffer injury from fertilisers, especially in dry weather, and fail to germinate Combined drilling in contact with the seed is therefore not advised for these crops. Yet it is precisely for these crops, which are set in wide rows, that general distribution is most wasteful. Possibly, better results with roots may come from attention to the second point—what is the best placement for bands of fertiliser? The problem would then be to find a position for the bands to ensure the advantages of economy of fertiliser, stimulation of early growth and hastened ripening, without damaging the germinating seed.

The Americans have done a lot of placement work on the potato crop. As has been said, this crop is not susceptible to damage by fertilisers. Yet their conclusions are applicable to cereal, and possibly to other, crops which are The following, amongst other, positions for the bands have been tried out: in contact with the seed; mixed with the soil in the row; above the seed; below the seed; at the side of the seed, at the side and slightly below: or again, 1 to 2 inches under; $1\frac{1}{2}$ inches above, mixed in the row; in the row not mixed; 2 inches to each side on the same plane; 2 inches to each side and 2 inches below seed level, 4 inches to e- side on the same plane. The general conclusion has·

that fertiliser is best placed two inches to the side of the seed and either level with it or slightly below it There is now, however, a question whether even higher yields of potatoes are not obtained by placing only a proportion of the fertiliser in bands, with the remainder generally distributed in the old way.

Placement of fertilisers is one of the means of securing higher output for less expenditure which we have neglected, though it has been incorporated into the farming practice of many countries. Thus the standard distributors used by American potato planters incorporate the findings of the scientists which have been mentioned above, but not so here It is possible that research workers in this country have been a little daunted by the empirical nature of the problem as put to them The fundamental chemistry of plant nutrition is not understood and therefore the line of progress is not clear. It is interesting, for instance, that the effect of "locking-up" phosphates, mentioned above, is not universal. it does not occur in many areas of Australia for example If we could apply that fact to our conditions, we might cut our present expenditure on phosphatic fertilisers to one-fifth But since scientists cannot yet explain that fact, they cannot yet tell us how to apply it

Too Much Tinkering?

At recent meetings of cattle breed societies the thyroid gland has got rather more attention than is usual at these gatherings. This gland regulates the plane of metabolism in animals, so that the development of young beasts and the productivity of mature beasts can be stepped up, in many cases, by feeding either natural thyroxin or a synthetic substitute in the form of iodinated casein.* At present the method is experimental, but it concerns breed societies from two aspects. In the first place, they are concerned with questions of pedigree and performance in

* The chief protein of milk, treated with iodine.

a competitive context: they regulate records and establish the breeding backgrounds of various cattle families on which commercial pedigree values depend. Now Nora may be an inherently better cow than Dolly, but the latter, primed with iodinated casein, might outyield her significantly, and the use of such stimulants can upset rankings no end. Secondly they are concerned with a long-term view of the health of their breed, and nothing is more likely to ruin that quickly than ignorant use of endocrinology by semi-bankrupt farmers. Acting on these two points, one Society has provided that, while records of treated cows shall be accepted by the Society, they must be distinctively marked, so that everyone knows the cows have been treated, and has also urged the Ministry of Agriculture to ban the sale of iodinated casein pending the completion of the Ministry's long-term experiments with it, which are designed to test its effects on constitution. The general impression at the debates of the other Society seems to have been that there was "too much tinkering" with cows nowadays.

The practical man is in a dilemma. He must produce as much of his product, in this case milk, as cheaply as he can. But it is not much use producing double this year if your herd is going to fold up with exhaustion next year. That is, he must not depreciate his capital for the sake of immediate income. At the same time he has the feeling that the routines he has been brought up in are "natural", though the modern milk-cow is, logically speaking, an artificial animal leading an artificial life. But if his word "natural" is taken in the sense "what is proved by experience not to depreciate my capital", he is making a valid point, and his conservatism is not stupid. The experiments with iodinated casein, for instance, will not be concluded this year or the next. It is common sense for a working farmer to let someone else be progressive, because he cannot afford the risks. This is why scientific discoveries are not rapidly applied to agriculture.

Scientists are not so interested in what is "natural", though the N.A.A.S. will of course have to pay attention to what is economic. Another peculiarity they have is to regard animals as existing for one purpose: they like to divide cows into *beef* cows and *milk* cows. Now the farmer likes a cow which gives a lot of milk and then fattens up well for beef when he has to get rid of her: he likes a "dual-purpose" cow, which the scientist calls a "no-purpose" cow. If cows gave wool and laid eggs that would please the farmer, but not the scientist. His object is the reduction of the animal to its specialised purpose, in the case of the dairy cow the production of milk. This implies three things:

Physical efficiency in the conversion of foodstuffs to milk.

Elimination of secondary products.

Regularity of production of milk.

Considerable progress has been made under the first heading, but further progress depends on a better understanding of the processes of digestion in ruminants than is ours at present.* Farmers are provided with a useful working system whereby to calculate the food requirements of animals whether they are in production or not, and most of them would be satisfied with what they are told on this topic. It is possible to ration the animal under the two categories of maintenance and production—what is sufficient to maintain it in condition and at a stable weight, and what is sufficent to enable it do a certain measured amount of work directly, as with the horse, or in produce, as with the sheep, pig or cow, over and above remaining merely stable. *Maintenance* rations will vary with the kind of animal, its weight and the amount of surface it exposes to loss of heat. Thus a fat bullock weighing about 1,750 lb. needs about 20,000 calories daily, whereas a sheep, which has a larger surface in proportion to its weight and also operates

* See for a fuller discussion of this question *Penguin Science News* No. 3, p. 159.

at a higher temperature, will require about 2,000 calories per 100 lb. Similarly a 6 cwt. cow requires 6/9 as much food for maintenance as a 9 cwt. cow, other things being equal. Tables are available to show how much of any particular food will produce the required quantity of calories. *Production* rations are expressed in terms of the product desired, pound of flesh, gallon of milk, and so on. For instance a cow giving three gallons of milk per day will require three times as great a production ration as one giving one gallon only, and here again the weights of particular foods to feed per gallon have all been worked out. If this knowledge is used by the farmer as intelligently as it has been presented to him, much waste of nutrients can be avoided and he has little need to complain about the digestion of ruminants. Scientists, however, are puzzled by various features which at the moment have slight practical application, but which might be important eventually. For instance, ruminants can digest cellulose. This in itself is something of a mystery, but the buffalo can live on rice straw and tree loppings. There is a future for any scientist who can persuade cows to digest cellulose as efficiently as buffaloes do. Ruminants also have a strange indifference to the amount of vitamin C in their diet: if it is short it is synthesised in the rumen and if there is too much it is destroyed. Simple nitrogen compounds like urea behave curiously when fed to ruminants. If fed pure or in solution they are quickly absorbed and excreted, but if fed in a close mixture with a cellulose material, part of the nitrogen behaves like protein or amino-acid nitrogen. These processes are not properly understood, because present ideas about ruminants' digestions are empirical.

Elimination of secondary products and regularity of production are matters for endocrinology and endocrinology is news, because it offers the exciting prospect of being able to gerrymander nature. The farmer's problem is to bring cows into milk, in the autumn, once every year. This entails production of a calf, which more often than not is slaugh-

tered soon after birth, and whose gestation detracts from the mother's milk production during the lactation preceding its birth. Calving in the autumn is made necessary by the winter-milk policy, since cows give most milk within 4 to 8 weeks after calving, on the average. Now the cow has a gestation period of some nine months. That is, to get autumn calvers you have to have them come on heat and be struck in the depths of winter, not intended by Nature for love, still less for artificial insemination. Many cows do not "bull" at all during the winter, or very infrequently. Heats last only a few hours, frequently between dusk and dawn, and may be almost without external manifestation. In the summer, by contrast, heats may go on for 36 hours or so and a great fuss is made by the cow for all to see. In practice heifers are usually calved down in the autumn fairly successfully, and as they grow older their calving dates move further and further through the winter into the spring, the natural time, but one when the price of milk sharply falls This is the importance of stilboestrol, which was dealt with in *Science News* 1, page 86. A detailed explanation will be found in that number of the method of action of the product, whose effect is to start animals ovulating fairly energetically, so that one can see and catch them It is in fairly general use, but does not act infallibly. If barren cows and maiden heifers could be brought into milk by injections of hormones or synthetic substances, they would not need to divert energy to gestation and could be made to produce regularly It is feasible in the laboratory but not yet in the cowshed.

Thus the picture of the dairy cow is that of an animal being rapidly altered from all purposes except milk-production. The farmer says there is too much tinkering about with her and is scared of damaging his capital or the breed he is interested in. The scientist cannot get on unless he delimits and defines his objectives; moreover that is his intellectual habit, the cow must be specialised The farmer's habit is to be ready to switch according to

the market: he wants to see a profit both at A and Z, not just at some refinement of A, unless it's a nice big one

Destruction of Aphides

The general idea seems to be that DDT and Benzene Hexachloride will kill any insect for ever. They are certainly effective, especially against sucking insects such as lice and mosquitoes, but results of their application to aphides have so far been disappointing Now aphides are currently described as the most serious pests of growing plants in this country and almost every crop has its particular aphis, such as the peach aphis, the potato aphis, the cabbage aphis, the large green aphis which feeds on peas, beans and clover, the woolly aphis of apples and the leaf-curling aphis of plums There are about a hundred varieties which harm our crops and many more innocuous ones. The damage caused is familiar to everyone in its direct aspect. The plant loses its vitality as the aphides suck its nutrients and sap; it is poisoned by the saliva they inject into it, so that, for instance, the leaves become distorted in various ways; its leaves are covered with the sticky honeydew the insects have to void because they have taken up more sugar from the plant than they can use Indirectly, aphides are a major factor in the transmission of virus diseases, for which their prodigious activity makes them very suitable. The annual loss caused by aphis-spread virus in the potato crop alone is estimated at something like £3,500,000 and the disease of sugar-beet known as "yellows", which we owe to the peach aphis, is one of the great limits to yield. These are only examples of a loss which, if it could be accurately estimated, would astonish most of us.

As has been said, aphides are not so susceptible to the new insecticides as some. Nor can they be controlled by the stomach poisons, such as lead arsenate, because they do not bite the surface of the leaves (They insert their mouths, which are like tubes, into the channels in which the food materials of the plant are transported and suck

them up.) They can only be killed by contact poisons and vapours. They are easily killed by preparations of pyrethrum or derris, or by nicotine The first two are applied as dusts or sprays and the third by fumigation, but the methods have in common their laboriousness and expense. Consequently they are not usually applied till the attack is seen to be bad—or rather, arrangements for applying them are not made until the attack is seen to be bad. By the time of applying, the infestation, which has a very short peak, may well be over, the damage done and not an aphis to be seen Even supposing a successful attack on the infestation at its peak, no control has been achieved over virus diseases. The influx of aphides in spring builds up to its peak gradually and the dissemination of virus is continuous from the first. By the time the aphides are noticed the virus is there, though the symptoms of disease may not be yet apparent. This is a dismal tale, but fortunately the aphis is subject to parasites and predators, against which it has no defence. It is attacked by a minute wasp, which lays its eggs in its body, and by a fungus. It is eaten by ladybirds, by the larva of the dirty-looking wasp-like fly which hovers about in July and August (the hover fly) and by the adults and larva of the Lace-Wing fly. It is very delicate, and an infestation can be washed away by heavy rain.

Eggs of aphides can be destroyed in winter by the ordinary tar-oil or DNOC winter wash. The difficulty here is that many species do not lay their eggs on the plants of which they are pests. It is one thing to destroy next year's infestation of your orchard by spraying in the winter, but it is quite another, for instance, to try to spray all the common spindle trees, on which next year's infestation of your beans and beet is brewing up. The eradication of the spindle as a national policy has been discussed, but it would clearly be very laborious. Furthermore the aphis in question (aphis fabae) can lay its eggs on the guelder rose, and might merely switch. The eggs of this aphis, probably our most

damaging species, are invulnerable to any frosts experienced here and are not attacked by parasites or predators Their survival till March, when they hatch, is therefore guaranteed. The unfortunate fact, however, has been turned to good use. If virtually all the eggs of aphis fabae to be found on the spindle tree in December and January will hatch, it follows that an estimate of the infestation of next year's beans and beet can reasonably be based on a count of the eggs. This hard work is carried out annually by the Advisory Dept of the School of Agriculture at Cambridge. Spindle shoots from various parts of the country are gathered in the middle of the winter and a count of aphis eggs is made which, by careful comparison with records from previous years, enables surprisingly accurate forecasts to be made. Of course it is only a second-best: it would be much better to be able to kill the eggs

The general point is, that in this particular matter of insecticides, where science has had some of its most publicised triumphs, no effective technique has yet been evolved against the most important pest, the aphis. there are remedies, but they do not amount to an economically feasible technique except in particular instances It is an illustration of the practical difficulties which meet the agricultural scientist. he does not just have to kill a hundred aphides out of a hundred in a cage; he has to work at a distance through human psychology and economics, rebellious unpredictables But we may still hope for results. Research, which is world-wide, has so far been more concerned to elucidate than to interrupt the complicated life-history of the aphis.

a region of nuclear dimensions and it looks, therefore, rather more reasonable to suppose that the motion of heavy particles only is involved in forming a nucleus.

Another and perhaps more important argument is this: in certain cases it is possible to increase the charge of a nucleus by one unit by means of the impact of a proton, which gets caught in the nucleus and dislodges a neutron, so that a charged particle has been substituted for an uncharged one. The resulting nucleus has more charge than is good for its weight and tends to reduce its charge by beta decay in which a positive electron is emitted. If after this we add one or more neutrons, the nucleus may now be too heavy for its charge and increase it by the emission of a negative electron We can now remove the spare neutrons, for instance, by bombardment with fast particles, and in this way return to a nucleus of the same weight and charge as the one we started with in the beginning. The net result is then that, apart from putting protons and neutrons into the nucleus and taking them out again, we have obtained a negative and a positive electron, and if these had come from a store inside the nucleus, the nucleus must now be that much poorer in electrons However, the nucleus which we have obtained will be in all appearances the same as the original one and we can, in fact, go on repeating this experiment indefinitely. Since there can hardly be an unlimited store of electrons inside, we have to conclude that at least some must have been produced in the process, and it is then more satisfactory to think that, in fact, all of them have been so produced.

5. *Doubts about Neutrons and Protons*

Once we have accepted the idea that not everything that comes out of a nucleus must necessarily have been inside to begin with, should we review our conclusion that neutrons and protons are inside? Here we seem on much safer ground, since these are nearly 2,000 times heavier than the electron, so that the production of even only one

neutron would involve an energy of the order of a thousand MeV. These amounts of energy are not usually available in nuclear transformations and while the production of heavier particles is, no doubt, possible in principle, it cannot take place in those transformations in which we usually observe the emission of protons or neutrons.

However, while the production of heavy particles is difficult, this is not necessarily true of a change in their nature. The neutron has about the same mass, i.e., it has about as much energy as a proton, and from the point of view of energy alone it should be quite easy to change the one into the other. We know, however, that electric charge cannot be created or destroyed, and hence if a neutron becomes a proton some positive charge must be disposed of or some negative charge used up. This is precisely what happens in the process of beta decay when, for example, a positive electron is produced. Since in this process the charge of the nucleus must go down one unit, a proton must have converted itself into a neutron. Another possible process is that a proton becomes a neutron, the charge being balanced by another neutron converting itself into a proton, i.e., the net result is that the two particles exchange their nature. There is reason to think that such an exchange is a very common process inside a nucleus, although the evidence for it is very circumstantial and there is as yet no very direct experimental confirmation. The question could be settled in the following way: if a very fast neutron collides with a proton it is likely to be deflected from its way by only a small amount and to give only a small velocity to the proton which it has hit. One would then expect that the passage of very fast neutrons through hydrogen should result in only a small spreading of the neutron beam and in weak recoils of the protons. If, on the other hand, the proton and neutron had a strong inclination to change their rôles, the neutron which proceeds on its way would now have become a proton and vice versa, so that we would expect the protons to go forward

and neutrons to stay behind. In the extreme form which I have described, this effect probably would require neutrons of energies of the order of 100 MeV, which are not at present available for measurements. But even at 20 or 30 MeV one expects a tendency of more protons or more neutrons to go forward, and such measurements would, therefore, settle the question of the proton-neutron exchange.

If this exchange is really a very frequent phenomenon it may not be possible to keep the identities of the particles clear while they are strongly interacting. It might still be possible to look at some point inside a nucleus and to say "Here is a heavy particle" but it might be rather more difficult to say with certainty whether what we have picked up was a neutron or a proton.

To summarise, we have so far seen that nuclei do not contain electrons and that they contain protons and neutrons, the total number of each kind being known from the known weight and charge of the nucleus, but possibly with their identities getting somewhat confused.

6. *Nuclear Forces*

What are the forces that hold the parts of the nucleus together? They can certainly not be electric forces, like those that confine the electrons in the atoms, for two reasons. First, because all the particles either have no electric charge or a positive one. Since like charges repel each other, this would never lead to attraction. Secondly, we need forces which are very much stronger than electric forces would be in regions of the size of a nucleus. A light nucleus is about 10,000 times smaller than a hydrogen atom, and since Coulomb's law says that electric energies go inversely as the distance between the particles, one would expect electric energies in the nucleus to amount to 10,000 times atomic energies, that is perhaps to a few hundred thousand electron volts, whereas nuclear binding energies are of the order of several millions.

There must, therefore, be a new type of force acting between these particles, and one can see at once that these must be "short-range" forces, that is to say, they must *diminish with increasing distance more quickly than electric* forces. Otherwise the interaction, in ordinary conditions, of two pieces of matter a fair distance apart should depend not only on their electric charge but also on the type of nuclei which they contain. This is not the case.

Indeed, the study of a collision between two protons (observed by letting beams of fast protons pass through hydrogen) confirms precisely the laws calculated on the *assumption of purely electric forces as long as the protons* are slow enough. With reasonably slow protons, i.e., of energies below about 1 MeV, the electric repulsion will prevent them from approaching closer than within 3×10^{-13} cm, which is just about the mean distance between particles inside a nucleus.

When, however, the proton energy rises beyond this value, strong anomalies are found in the scattering which can be explained only by assuming that a new *attractive* force begins to act at about that distance. Similar results have been obtained from the interaction of neutrons with protons at low energies.

A good deal of information has been collected about the force between a neutron and a proton. Some of it comes from the study of collisions between neutrons and protons (passage of neutrons through hydrogen). More can be inferred from the properties of the deuteron, *i.e., the* nucleus of "heavy hydrogen," which is made of just one proton and one neutron.

This nucleus plays the same important part in nuclear physics as the hydrogen atom (one proton and one electron) in atomic physics. Unfortunately, while the hydrogen atom has a series of excited states which give rise to distinctive spectral lines which could serve to test any theory, the deuteron has no excited states, since the forces are only just sufficient to hold the two particles together in their

state. Any extra energy given to them is sufficient to tear them apart

We, can, however, study the way in which the deuteron breaks up, for example, under the effect of gamma radiation, and also the reverse process, the capture of a neutron by a proton, when the surplus energy comes out in the form of gamma rays

As to the forces between two protons, the scattering of protons by hydrogen has already been mentioned. A collision between two neutrons cannot be observed with present techniques What we know about neutron-neutron forces comes from the following reasoning. Compare two nuclei such as helium 3, containing two protons and one neutron, and hydrogen 3, with two neutrons and one proton. Their masses and other properties are so similar that one can conclude that their only difference is due to the electric charge on the extra proton, and the slight difference between neutron and proton mass, but that the nuclear force between two protons and that between two neutrons is the same This conclusion is borne out by similar comparisons in all other cases where data exist.

More evidence on all these forces can be obtained by studying the binding energies of heavier nuclei, but here the evidence becomes more circumstantial and is not so easy to summarize

In this way it has been possible to form a fairly close estimate of the range of the forces, i.e., the distance over which they are effective, and of their strength at close approach. The precise law of variation of force with distance, however, is not yet known at all accurately.

7. *Refinements*

In studying, for example, the scattering of neutrons by protons, it is found that some neutrons are scattered in a manner quite different from what one would have expected from the forces which we deduced from their interaction in the deuteron.

This apparent contradiction has been shown to be due to the fact that nuclear forces depend on the spin directions of the two particles. In quantum theory each particle, such as an electron, proton or neutron has a "spin," as if it were revolving about its own axis with constant speed. The spins of two such particles which collide, must always be either in the same or opposite directions.

It turns out that the force depends on whether the one or the other is the case. The attractive force is stronger if the spins are parallel, and this is the case in the deuteron.

For opposite spins the attraction is not strong enough to give a bound state at all, and no deuteron in which the spins are opposed is possible

Moreover, the proton-neutron interaction may depend on whether or not the two particles happen to be in exactly the same state of motion.

To understand this, we must remember the possibility mentioned before, of the two particles changing their rôle, or what amounts to the same, proton and neutron changing places. This exchange process is not possible if they are in different places since it would involve a sudden jump. So the exchange can take place only if the particles are as nearly in the same place as, within the laws of quantum mechanics, we can tell Similarly they must be moving, as nearly as we can tell, with the same speed If this exchange process contributes at all to the interaction energy of the particles the resulting force will therefore be different according to whether the particles are in the same state of motion or not

In the case of two like particles, say two protons, this distinction does not arise, since there is a strange law in quantum mechanics, discovered by Pauli, according to which two like particles can never be in the same state of motion and also have parallel spin This law leads to the known structure of the atom, in which only two electrons (with opposite spins) can be in the most stable orbit or "K-shell", two in the next higher one, etc. Hence for

particles the question of exchange does not arise, and the only refinement here is the dependence on spin.

We believe that the laws of quantum mechanics which have been found applicable on the atomic scale, are also valid in the nucleus, and that only the nature of the forces acting between these particles is different. If this is right, then, if we could only find out exactly what the forces are, we could work out what the properties of any particular nucleus should be. At the present this programme is held up for two reasons. The first is that our knowledge of the forces is still very crude. The second reason is that once we deal with any problem involving more than three or four particles, the purely mathematical complications in solving the problems, assuming the forces to be known, become almost prohibitive. In fact, already the problem of three or four particles is very terrifying even to a mathematician with a high degree of skill and courage, and only lately very ingenious methods have been devised that allow us to deal with these problems with quite a reasonable effort.

The situation is even more complex than the above picture would indicate. It had always been taken for granted that the force between two particles was a "central" force, i.e., one pulling the one particle in a direction towards the other or away from it, but there is no reason why this should always be the case.

If the forces were such central forces, one would expect most nuclei to be spherical in shape, and in particular in the deuteron one would expect the neutron and the proton to run about each other so that the line joining them would be equally likely to point just in any direction in space. This means that the region occupied by the proton or neutron on the average would again be a sphere. However, very ingenious experiments by Rabi and his collaborators on the effect of electric fields on the deuteron have revealed the fact that the deuteron is not spherical in shape but elongated like an egg. This must be due to forces

which tend to push the neutron and the proton into a certain direction relative to each other. Once the existence of such "non-central" forces was discovered one had to see how much of the mathematical work done previously with central forces could still be trusted. This process is still going on, but again the fact that we have no information of the precise nature of the forces and, for example, their dependence on the distance between the particles, is a serious handicap.

8. *Nuclear Reactions*

From what I have said so far, one might gather that, until we have a better knowledge of the nuclear forces, we cannot describe in detail what goes on inside a nucleus. That is not a correct impression, since it turns out that many of the properties of nuclei, and in particular the nature of nuclear reactions, is not at all sensitive to the precise nature of the forces, so that there is a good deal we can understand even on the basis of our present vague knowledge of the forces. It all adds up to a rather satisfactory picture, which was built up following the ideas of Bohr. What we know is that the nucleus behaves rather like a drop of liquid, roughly spherical in shape, or somewhat egg-shaped to be precise, with the density much the same for heavy or light nuclei. On being disturbed, for instance, by a collision with another particle, the matter inside the nucleus is set into irregular motion. This is violent even if the colliding particle was very slow, since the short-range attraction speeds it up on its final approach to the nucleus; it therefore arrives with a proper impact. Like a billiard ball that collides with a cluster of other balls on the table, the particle shares out its energy with all the others and in general none of them is left with enough speed to overcome the attraction and get away. Whether in the subsequent motion one of the particles happens to pick up enough speed to get away, is a matter of chance; in any case it will take a little while before this happens. Until

the nucleus holds together like an atom or molecule and, just as in those cases, definite energy levels or quantum states are prescribed for the nucleus. In this way there exist fairly sharp energy levels for a nucleus even when its energy is high enough for one of the particles in it to get away. The result of a collision depends, then, very much on whether the extra particle arrives with a velocity that will leave the combined nucleus, with this new particle added, with an energy just equal to one of the quantum states. In this case one speaks of "resonance". If there is no resonance the extra particle will not be able to get into the nucleus at all.

The description of nuclear reactions depends, therefore, on the position of the resonance levels and their properties. Their precise position, of course, cannot be predicted without a very reliable knowledge of the forces, but about their general properties quite a lot can be found out. For instance, we can study the way in which the result of a collision depends on whether the energy is very exactly equal to that of the resonance level, or whether it is a little different from it. The results have been found to agree very well with the general theory and this confirms the belief that the general laws of quantum theory hold for the nucleus as well as for the atom

9 *Meson Theory of Forces*

So far I have talked about the forces between nuclear particles as something given without enquiring where they come from. Let us turn for a moment to the atom by way of analogy. We know that an atom is held together by electric attraction, which is governed by Coulomb's law about the attraction of opposite charges. This means two electric charges held at a distance from each other attract or repel each other, as the case may be, and this can be verified easily on a larger scale in the laboratory. It is not satisfactory, however, to think that a body can exercise a *direct* influence on another at a distance, without bringing

in some means by which this effect is transmitted from point to point. In the case of electric forces this is, in fact, described by Maxwell's idea of the electromagnetic field, which exists at any point in space and which transmits disturbances locally. In the same way, for instance, the turning of a light switch in your house does not have a direct effect on the lamp, which may be some distance away, but it causes a change in the voltage of the conducting wires nearby, which will be transmitted from place to place until it reaches the lamp.

We know also that such electromagnetic disturbances travel in empty space with the velocity of light, and light is simply a particular form of such a disturbance.

Now, in the quantum theory a light signal cannot be sub-divided indefinitely, but consists of finite units, so-called light quanta, or "photons", each carrying an amount of energy proportional to the frequency of the light wave of which they form part These behave in many ways as if they were definite particles. Only, since massive particles could never move with light velocity, they are particles without mass and they can never be stopped without making them disappear altogether.

Things are quite similar as regards nuclear forces. One would again look for a kind of field which transmits the force between, say, a neutron and a proton, only in this case the particles into which such a field can be resolved cannot be particles without mass. If they were, the law for the forces would come out precisely the same as that for electric forces, and we would then not be able to account for the existence of short-range forces. If, however, we assume that this field is made up of particles with a finite mass, then we obtain short-range forces; in order to get the right sort of range we have to assume that their mass is about 200 times greater than the electron mass, or in other words about one-tenth of that of the proton. Such particles then are intermediate in mass between those previously known, and they are now called "mesons". T

reasoning I have given here is substantially that used by the Japanese Yukawa in 1935, and shortly afterwards it was discovered that particles with just about that mass existed in cosmic radiation These particles were found to carry one unit of electric charge like the electron or the proton. There may also exist similar particles without charge, but they would be much harder to detect

Just as electric forces arise from the possibility of one charge giving out a light quantum and the other accepting it, the nuclear forces would require the possibility of one particle giving out a meson and another absorbing it. If this involves charged mesons then, for instance, a positive meson could only be given out by a proton, which in the process would turn into a neutron, and it could only be taken up by a neutron, which would thereby become a proton. In this way the overall result is that the two particles have changed their nature and this leads in a natural way to the exchange forces which I have described before. The same mechanism, however, will not produce any interaction between two protons. To account for proton-proton and neutron-neutron forces, we have to postulate that there exist neutral as well as charged mesons.

This meson theory of the nuclear forces is extremely attractive, but there is as yet no direct evidence in its favour. Recent experiments, in fact, make it likely that the picture is a good deal more complicated than appeared at first. For example, recent work at Bristol by Powell's team has proved that in cosmic rays there exist at least two kinds of mesons with somewhat different weights, and that the heavier one can change into the lighter one, part of the mass difference being set free as energy.

In any case it has not yet proved possible to work out consistently the consequences of the meson theory of the forces, since this needs the application of the methods of quantum theory to a continuous field. Already in the case of the electromagnetic field this proved to be one of the most stubborn problems of modern mathematical physics

and while many people have tried to overcome the difficulties, no satisfactory solution has yet been found. It is not surprising that the same difficulties have appeared in the case of the meson field and that they, too, have so far defied any attempts to solve it. It is becoming more and more likely that what is needed here is not just a slight mathematical refinement of our existing methods, but something completely new and important.

Whether this new step forward will ultimately be developed by altering our description of the known facts and thereby bringing order into them, or by new discoveries of phenomena of which nothing is yet known, remains to be seen.

There is in any case no doubt that our knowledge of all these problems will make an enormous step forward when physicists succeed in accelerating particles to energies of several hundred MeV, since it is then likely that one will be able to produce mesons at will, rather than work with the scanty supply provided by the cosmic rays.

10. *Beta Decay The Neutrino*

I have already referred to beta decay, i.e., to the possibility of a nucleus changing its charge and producing an electron (positive or negative) in the process, but there is more to it than that. One would have expected all the electrons coming out of a given type of nucleus to have the same velocity, so that the energy they take away would just balance the energy change in the nucleus. But very early in the work on beta rays it was found that electrons from any substance undergoing beta decay covered a very wide range of velocities. This might mean that either the nuclei from which the electrons came, or those left behind as a result of the process, had varying energies, but in all other ways all nuclei of a given type appear quite identical and, for instance, no variation could be detected in their weight. By studying the energy balance in other reactions involving the same nuclei, it was established that the

would just balance for the fastest electron that occurred in the beta process. Whenever an electron with less energy came out, and this was in the overwhelming majority of cases, some energy appeared to have got lost.

Physicists were very reluctant to think that the law the conservation of energy might not apply in this, since this law was of such fundamental importance been established in so many other parts of physics.

The alternative is to assume that the missing energy given out in some new form, in which it escapes detect The hypothesis was proposed by Pauli that an particle with no electric charge and of small mass produced together with the electron. Fermi, who this hypothesis a good deal further, gave this partic name "neutrino".

There is another reason to believe in the existence of new particle I have explained that electrons, prot neutrons each have a spin, even apart from their about each other Quantum theory teaches that the spin each particle is just one-half of the smallest angular mentum that two particles can have when revolving ab each other. Let us consider a nucleus of which the number of neutrons and protons combined is an number. Its spin, therefore, consists of an even numbe half units or, in other words, a whole number of un plus the effect of their motion which again gives a wh number of units. After the electron has been thrown as a beta ray the total number of neutrons and protons not changed, so the total spin is still a whole number, the electron has now carried away one half-unit of The motion of the electron contributes whole units cannot, therefore, make up for the discrepancy. This pro would, therefore, violate the conservation of angular mentum, which is as basic as the conservation of en If there is a neutrino it would be perfectly reasonab expect it also to have half a unit of spin like the particles and this would immediately remove the troub

So far, however, evidence for the neutrino is entirely circumstantial. It is true that the Fermi theory gives quite a satisfactory description of such details as the velocity distribution of the beta electrons, but one would like to be able to pick up a neutrino occasionally, instead of only losing them all the time. Now it is quite true that if neutrinos can be thrown out by a nucleus, it must also be possible to catch them again, but both are very rare phenomena. Beta decay is very slow compared to the times taken by other nuclear reactions, and one must, therefore, expect the reverse process, i e, the capture of a neutrino, also to be very rare. On the Fermi theory, a neutrino could indeed go very many times across the interior of the earth and still have practically no chance of hitting anything on its way. This makes the neutrino a very elusive particle, but no physicist will give up hope that one day a method might be found by which to show it up

11. *Conclusion*

It would have been much easier to write this article fifteen years ago. Then our knowledge of nuclei made a very much tidier picture. There were fewer elementary particles and it appeared likely that the remaining gaps in our knowledge about them could be filled rapidly. We now know that this was due to our ignorance, and that these gaps contained a wealth of new facts which we then did not even suspect. A new landscape has been opened up and it will take us time to find our way about in it, but just this bewildering variety of new things makes nuclear physics one of the most exciting branches of Science to-day.

Diatoms

BY N. INGRAM HENDEY

Where They Are Found

THE study of diatoms has been tied necessarily to the development of the microscope as an aid to vision, and many of the early records are confused and unreliable. It seems quite certain, however, that the famous Dutch observer, Antony van Leeuwenhoek, was engaged in correspondence with English observers concerning the wealth of minute living organisms which the microscope revealed, and the first published description of a diatom was given by an unknown English microscopist as early as July 5, 1703 This account, in the form of a letter to Leeuwenhoek, together with an accurate illustration, appeared in Philosophical Transactions of the Royal Society (1703). The unnamed writer had examined a drop of pond water which contained the common Lemna or "duck-meat" and had observed diatoms attached thereto

Diatoms are to be found practically speaking wherever there is water and an adequate amount of light. Freshwater forms are found in every pond, stream and wayside ditch, in all parts of the world. They are found in the mountain-top lakes of Titicaca in Peru, at an altitude of 10,000 feet, and in the thermal springs of Yellowstone Park and of Kamchatka, where the temperature of the water is more than 50°C. Another section of the freshwater flora inhabits the thin film of moisture that invests soil particles. *En masse*, diatoms appear as a greenish-brown scum floating upon the surface of the water, or as a film covering mud or stones at the bottom of ponds, ditches, etc. Others form frondose colonies and attach themselves to plants or debris in the water. The marine flora extends over all the oceans

from the polar ice cap to the tropics, and constitutes the largest vegetable element in the vast floating fields of microscopic life referred to as "plankton".

All diatoms are unicellular, and each individual cell is capable of carrying out all the vital functions of life, and reproduces by the simple method of fission. They live mainly free and unattached, but some species link themselves together to form chains, or live within a specially secreted mucous sheath or envelope and assume the appearance and habit of a small filamentous seaweed, attaching themselves in like manner to larger objects immersed in the water. One species in the Antarctic inhabits cracks in the skin of the whale, while another is found in oyster beds. Most species are very sensitive to the chemical and physical factors of their environment, and truly freshwater species never are found living under marine conditions of the open sea, and vice versa, although a brackish water flora exists which has a considerable toleration for sodium chloride and is found sometimes in fairly fresh waters, as well as in coastal waters, particularly in estuaries.

Diatom productivity in the surface waters of the great oceans shows a very marked seasonal variation. Two clearly marked maxima are to be observed, one in the spring, and the other in the autumn, the former being the more intense, particularly in polar waters. The limiting factors are not always the same for different areas, but it appears that the exhaustion of nutrient substances, such as phosphates and nitrates, and available silica for structural purposes may inhibit diatom growth. During periods of great diatom activity the surface waters may become so densely populated that sea birds alighting in search of food frequently get their feathers so clogged that they are unable to rise again. When the organisms die the tiny cells sink slowly, the organic material becomes disintegrated by bacterial action, and the siliceous frustules (their characteristically sculptured shells) collect on the floor of the ocean to form a deep-sea ooze. During geological time deposits of considerable thick-

ness accumulate, and cataclysmic movement of the earth's crust may raise the floor of the ocean and cause the waters to be drained away, leaving the diatoms high and dry, often to be overlaid by lava, volcanic ash, or some other geological formation. The superimposed layers exert a pressure upon the diatom deposit and compact it into a hard rock-like substance Vast deposits of fossilised diatomaceous earth exist in many parts of the world, the more important ones being in Germany, Algeria, Kenya, and California. In Britain small deposits have been found in the Kentmere district and in certain islands off the west coast of Scotland The Californian deposits are among the largest and purest in the world and attain a thickness of more than 1,000 feet over a very considerable area. Some idea of the geological time required to form such a deposit, and the number of organisms involved, can be gained by realising that after death, small organisms such as diatoms would take several years to fall to the bottom of the ocean, and that each cubic inch of diatomaceous earth would contain something like 60,000,000 cells.

Structure of Diatoms

Viewed under a high-power microscope, diatoms are not at all plant-like in appearance, for there is no differentiation of parts into stem, leaves or roots, as in ordinary plants. Each plant consists of one single cell microscopic in size, varying from 4 microns up to 500 microns in diameter, or let us say from 1/6000 inch up to 1/50 inch. These dimensional extremes are enjoyed only by a few, while the bulk of the species recognised (there are about 15,000 sorts in all) vary from 25 microns to 200 microns in diameter, that is, from 1/1000 inch to 1/125 inch approximately. The cell is basically the same as the cells of the higher plants and contains the central, all-important nucleus suspended upon a network of protoplasmic strands, accompanied by a number of coloured bodies, called chromatophores. These chromatophores are often flattened kidney-

shaped, or roughly spherical bodies, and contain the chlorophyll, a green pigment common to most plants, together with a brown pigment called diatomin These two coloured substances control the photosynthetic processes by which in the presence of sunlight the plant is enabled to form nutrient materials necessary to its life. The chromatophores may be regarded, therefore, as laboratories in which complex organic foodstuffs are produced from relatively simple substances. All these elements are contained within an extremely tenuous membrane, the perizonium. Thus far, the diatom cell is very like that of any other plant, but differs from it very markedly in the following respect. The diatom deposits an outer coating of non-crystalline siliceous material, a white substance allied to quartz. This outer coating or frustule, as it is called, is quite hard and rigid, and is deposited in a perfectly symmetrical manner. The frustule is really a box, composed of an upper and lower lid, each fitted with a girdle band around the edge The upper lid and girdle is slightly larger than the lower, over which it fits, in the manner of the lid of a pill-box. The two halves, or valves as they are called, are otherwise identical in all respects.

The shape of the frustule may vary considerably. Many of the marine ones are circular, or broadly oval, others triangular or quadrangular, while most of those which live in fresh water are boat-shaped. The surface of the silica frustule is exquisitely ornamented with radiating or curved lines, which may be thickenings in the silica, or more often, perforations through it. These markings are characteristic of the species. Most of the markings are very difficult to see, even with a good microscope, and in some species they lie at the limits of resolution in white light, that is, the lines are in the neighbourhood of 125,000 to the inch. The electron microscope has placed in our hands, however, a new powerful tool, which shows that many of the perforations have an internal plate, which is again perforated, the ultimate perforations being of the order of 100 A.

units in diameter, or somewhere in the neighbourhood of 1/2,500,000th of an inch. Whatever the true nature of these markings proves to be, they are arranged over the surface of the frustule in an endless array of design, which makes the diatom one of the most beautiful objects in the natural world. The existence of infinite beauty in Nature, particularly in microscopic things well below the range of normal vision, has always been a subject for speculation. In the diatom the structure is undoubtedly functional, that is, the perforations have a job to do (see below), but no apparent reason is immediately forthcoming for the arrangement of the performations in the form of a pattern. Here structure is arranged to produce a design. The endless pattern may be functional also, in an obscure way, but for the moment it appears that Nature is utilising Design without Reason.

One extraordinary feature of the design upon diatoms is the precision with which it is reproduced. It was stated earlier that the diatom frustule was in the nature of a pill-box, and when the cell is about to undergo reproduction the lids of the box move apart slightly until the edges of the girdles are almost parting company. This movement of the valves brings about an increase in the internal capacity of the cell by adding to its depth. Nuclear division then takes place, and the daughter-nuclei take up positions at opposite ends of the cell. The protoplasm divides and surrounds the two newly-formed nuclei and two new valves are formed inside the mother-cell. When the formation of the new valves is complete, the two daughter cells part and continue a separate existence Thus each diatom consists of one old valve and one new one. Generation after generation, throughout many millions of years, the design which is characteristic of the species is faithfully reproduced. It will be seen also that as the daughter-cells are formed *inside* the mother-cell and that the two new valves are the lower and smaller ones, repeated division is attended by a gradual reduction in size This reduction in size, or rather in diameter, is not allowed to proceed too far, for a sexual process

usually intervenes which brings about a re-establishment of size. *It appears therefore that diatoms start their life fully* grown and that the size of new cells is limited by the size of the parent cells from which they spring, for once the rigid silica framework is deposited and the design determined, no growth that would require an increase in diameter is possible—the only growth that is permissible is brought about by deepening the girdles of the valve, that is, on an axis at right angles to the valve surface.

In outline, diatoms have exhausted every shape, exploiting three basic forms, often combining them to produce infinite variety. Let us consider some of these forms Firstly there is the naviculoid or boat-shaped outline, where the ratio between length and breadth varies to produce everything from that which is needle-shaped to that which is broadly oval Examples of this form are seen in Plates 23 – 27. This type of outline is predominant in freshwater diatoms. Secondly, there is the truly circular outline; this is modified to produce broad ellipses as well as ovate and panduriform outlines. Thirdly, there is the polygonal outline. Forms possessing three, four and five angles are common, while others possessing up to 21 angles have been discovered. Forms in the last two categories are more common in marine waters, the polygonal ones being particularly numerous in the great fossil deposits of the Miocene. Examples of circular diatoms are seen in Plates 28 – 33, and of polygonal ones in Plates 34 – 38.

These examples have been chosen not because their beauty is any more marked than that of others, but because they show clearly the types of structure employed by some of the most common species, representing both living and fossil floras.

Recent research into the structure and physiology of diatoms has indicated that the siliceous frustule of the organism is not merely a rigid covering surrounding the soft and vital protoplasm in order to protect it, but that the perforations through the valves of the frustule

interchange between the cell contents and the aqueous medium in which the organism lives. This peculiar perforate structure may account also for the movement of diatoms. Movement in living diatoms is restricted mainly to those forms which are boat-shaped. These forms possess a central mid-rib with lines of perforations arranged with reference to it. This movement, one of the most fascinating phenomena to observe under a microscope, has mystified microscopists for a very long time, for it takes place in complete absence of any visible organs of locomotion. The tiny boat-shaped cells move either in a graceful glide, or in slow hesitant jerks, proceeding half majestically or half comically in their watery world, propelled as it were by unseen hands. It may be that the diatom forces water from the cell through the perforations in its siliceous skeleton, causing the organism to move forward. If this is the explanation of the curious method of locomotion, it means that Nature has forestalled Man in the discovery of jet propulsion.

Economic Use of Living Diatoms

The rôle of micro-organisms in Nature varies considerably and is determined to a large degree by whether the organism is a plant or animal The diatom, being a microscopic plant, forms part of the "producer population" and is concerned during its lifetime with building up complex foodstuffs from simple substances This building up, or synthesis, is accompanied by a liberation of oxygen, and the process results in a twofold general enrichment of the surrounding area Soils in particular, whether of the kitchen garden or the corn-producing prairie-lands, depend very largely for their productivity upon their microbiological content, and surface soils rich in diatoms tend to favour the germination of young seedlings.

The diatom population of surface waters may act in a somewhat similar manner. The large diatom community supported by lakes and reservoirs liberates oxygen into the surrounding water, thereby aerating and purifying it. This

is the normal activity of all green plants in water, such as Duckweed, Canadian Pond Weed and such other plants which form a green film over the water, but as the seasonal maxima for diatoms occur in the very early spring and late autumn, before and after the other forms of pond plant life, diatoms act beneficially by prolonging this purifying period, as well as by adding to its intensity.

The rôle of the diatom in reservoirs of drinking water is somewhat complex and deserves more detailed attention. The main problem of such undertakings as the Metropolitan Water Board is to provide water suitable for human consumption. The water must be of good physical quality and free from obnoxious substances which would impart an objectionable taste or smell. More important still, the water must be free from pathogenic bacteria which might be injurious to public health. In order to ensure the requisite standard of purity a complicated system of filtration and chlorination has been introduced together with biological control of reservoirs and constant chemical and bacteriological examination. To the water engineer, the presence of diatoms in the reservoir may be a blessing or a curse. Reservoirs which derive their water from a cultivated area such as the Thames basin are rich in nitrates, phosphates and silica and are liable to great outbursts of diatoms during the spring. For example, a population density of more than twenty million cells per litre would not be unusual. When the organisms die, the cells disintegrate and liberate vast quantities of organic substances which greatly favour bacterial development, resulting in a rapid consumption of oxygen. One result of an oxygen deficiency is an increase in the growth of anaerobic bacteria and fungi which may give rise to unpleasant tastes or smells and render the water undrinkable. Another aspect of the same problem is that upon the death of the diatoms, the siliceous frustules put an additional strain on the filters. A reservoir supplied by Thames water with a volume of nearly seven million gallons, might contain anything up to 110 tons of

the diatom *Fragilaria crotonensis*, measured as a dry weight. Such an immense diatom swarming would involve a daily removal from the water by filtration of an amount of diatom silica equal to one ton, dry weight. Such enormous quantities of plankton diatoms in the reservoir cause trouble by blocking filters, particularly of the "rapid" or "pressure" type. Slow sand filters, on the other hand, owe their efficacy almost entirely to their biological components, one of the chief being the diatom. These slow filters are usually exposed to light, and filtration is effected by the water passing through a skin or film of diatoms and bacteria. The diatoms collect mainly on the surface of such a filter and render a great service by producing oxygen as a by-product of their photosynthesis. This assists in the oxidation of organic materials and prevents the lower layers of the filter becoming anaerobic, and fosters the growth and development of oxygen-requiring bacteria which in various ways improve the palatability of the water.

The diatom population in the marine plankton is most important, as it plays a vital part in the economy of the seas, for not only does it oxygenate the water, but becomes the basic link, the grass as it were, in the food chain of all the other creatures which live in the sea. Whales, for example, travel southward from their breeding grounds as the ice breaks up, in search of the great plankton fields, the grazing grounds of the far south. Here, just as much as in the English countryside, the richness of the pasture decides the fatness of the herd. The plankton diatom also plays an important rôle in oceanographical research. Diatoms serve as indicators of the direction of flow of the oceanic currents in which they live, and in the South Atlantic particularly, the diatom has helped very considerably to plot the position of the convergence-zones of the various masses of water which go to make up the South Atlantic and Southern Oceans.

One other economic aspect of living marine diatoms will be considered, that is, the part they play as fouling

organisms upon the hulls of ships. When any surface is immersed in seawater, under natural conditions, it quickly becomes fouled with marine organisms. The algal fouling of ships at the waterline by a green seaweed, usually a species of Enteromorpha, is a sight common enough to all who have visited docks where ships lie at anchor, but often, far down below the water-line the hull may be fouled by a strange assemblage of creatures. Amongst these may be found the barnacle and the tube worm, whose outer coatings form hard chalky concretions, together with delicate colonies of hydroids such as Tubularia and Obelia and soft bodied, jelly-like Tunicates. This fouling does very little actual damage to the metal structure of the ship, but increases surface friction, which retards the vessel as it moves through the water. In order to overcome increased friction due to fouling, more fuel must be used if the rate of speed is to be maintained. It is estimated that on a heavily fouled ship an increase of fuel consumption of up to 40 per cent may be required. This, in peacetime is a serious drain on fuel stocks, and in times of war even more so; further, loss of speed due to fouling may result in the loss of a valuable convoy or may adversely affect a naval action. To prevent marine fouling, ships and dock installations are usually painted with an anti-fouling composition. Anti-fouling paints contain, amongst other things, toxic substances, such as compounds of copper and mercury, but their exact mechanism is as yet imperfectly understood. probably the toxic salts leach from the painted surface, and act as protoplasmic poisons. Research has shown that not all marine organisms are equally sensitive to copper and mercury, and that certain species of diatoms are highly resistant. This means that a freshly painted surface may be leaching sufficiently highly to repel the more sensitive organisms, such as the settling stages of barnacles or hydroids, but will permit successful colonising by resistant diatoms. These diatoms, finding themselves

position where they do not have to compete for living space, and in which they are more or less free from attack by organisms seeking them as food, tend to multiply rapidly and form together with bacteria a slime film upon the submerged surface of the ship Observations have shown that an anti-fouling paint which favours the production of a heavy slime film tends to protect against the attachment of barnacles and other fouling organisms. In this manner it may be said that diatoms themselves act as anti-fouling agents.

Fossil Diatoms

Enormous beds of fossil diatoms are found in various parts of the world. They are the floors of the long-forgotten Tertiary seas which covered parts of North America and Central Europe some 60 million years ago. The majority of these Tertiary beds are associated with basalt lava flows, which in many instances lie both above and below the diatomaceous strata. Until comparatively recently it was believed that the most ancient and most prolific period of diatom growth was during the transition from Mesozoic to Tertiary, and that a peak was experienced in the warmer Miocene seas. Recent work, however, by Dr. G. Dallas Hanna of the California Academy of Sciences, has proved the existence of a large diatom flora in the Moreno shale, a well defined Upper Cretaceous stratigraphic unit extending along the west side of the San Joaquin Valley, in the Panoche Hills, California Deposits of fossil diatoms are known by several names, the most common of which are diatomaceous earth, kieselguhr, molera and diatomite. Although diatomaceous earth occurs in most countries, it is worked commercially in but a few, as most deposits are small in extent or of impure quality, and could not be operated economically. The United States of America is the world's largest producer of diatomaceous earth, and Algeria is probably the second largest. In California the deposits are almost continuous between Los Angeles and

San Luis Obispo, reaching a maximum in the Lompoc area. The purest of these are marketed under the trade names of *Filter-cell*, *Super-cel* and *Hyflo super-cel*. Diatomaceous earth is used either in blocks cut from the natural deposit without further treatment, or it may be crushed, calcined to remove organic impurities, and graded by air-blown separators. When thus purified it is a white or creamish white substance resembling chalk. It occurs in nature in varying degrees of purity, and the following analysis of an air-dried Canadian sample gives a good idea of its percentage composition.

Silica (SiO_2)	83.20
Alumina (Al_2O_3)	3 80
Iron Oxide (Fe_2O_3)	3 00
Lime (CaO)	0.80
Magnesia (MgO)	2 23
Potash (K_2O)	0 89
Soda (Na_2O)	0 33
Water and organic matter	5 26

Economic Use of Diatomaceous Earth

The chemical and physical properties of diatomaceous earth make the material admirable for many scientific and industrial purposes, the most important of which are

(1) filtering medium
(2) insulator against heat, cold, and sound
(3) catalyst carrier
(4) absorbent
(5) filler
(6) building material
(7) abrasive
(8) pharmaceutical preparations
(9) stratigraphic indicators

Filtration

In many industrial and commercial undertakings, filtration is an important process, and the filtering medium should be insoluble in the liquid to be filtered, chemically inert,

quantities for insulating purposes are mined in Jutland, where it is known as "molera". Here again, successful use of the material depends upon proper consideration being paid to the size and shape of the diatoms contained therein. The low thermal conductivity (approximately 0.000127 gramme-calorie-seconds at 200°C) of a diatomaceous earth, containing a preponderance of large unbroken forms, makes it one of the best insulators for temperatures below dull red heat. Insulation at higher temperatures calls for material in which there will be increased porosity due to an increase of the fine perforations or air-spaces per unit volume of the material. This is probably due to the fact that at high temperatures there is a high rate of radiation and convection through air, which increases markedly with further rises in temperature. It follows, therefore, that insulation at high temperature is best obtained by using diatom material in which predominate very small uniformly shaped cells of the same size, through which pass the greatest number of perforations.

Diatomaceous earth from parts of Central Europe and from New Zealand are admirably suited for this purpose. It follows also that solid impurities such as silt or powdered quartz will act as conductors and will lower the insulating value of the material. Diatomaceous earth may be used not only for insulating against heat or cold, but also against sound. Bricks sawn from the natural deposit may be used to line telephone kiosks, libraries and audition rooms of broadcasting studios, where it will perform the dual role of fire-proofing as well as insulating. The problem of using diatomaceous earth for insulation has been dealt with but briefly, but its general application in this field is very extensive. The material may be used in powder form or in natural or bonded bricks or slabs for steam plant equipment, for lagging pipes and boilers, in smelting furnaces, in ceramic plant equipment, for lining kilns or enamelling furnaces, and in many other ways where it is desirable to provide insulation against loss of heat. Plate 41 illustrates

diatoms found in "molera", the Jutland deposit, so extensively used in the form of refractory bricks, sawn from the natural deposit.

Catalyst Carrier

Diatomaceous earth is used as a catalyst carrier in the hydrogenation of oils for the manufacture of soap. A soluble salt of nickel is mixed with a quantity of diatomaceous earth, sodium carbonate is added, and the mixture boiled. The product of the reaction is passed through a filter-press where the plates retain the earth together with the nickel carbonate formed by the reaction. The filter cake is removed, dried and heated to 300° C. in an atmosphere of hydrogen, where the nickel carbonate is reduced to the state of a finely divided black powder. This powder is th transferred to the vats of oil, and hydrogen is p through under pressure These conditions induce a hydro atom to be transferred to the oil, converting the oil stearine.

Absorbent and Filler

The low apparent density and high po aceous earth makes it an excellent mediu dangerous or corrosive liquids It may be to pack strong mineral acids, bromine, extensively to carry disinfectants and stances and has been used with some su for fungicides and fertilising agents. Di was employed to absorb the nitroglycer form of dynamite. About 25 per cent of was required, but this amount reduced the of the mixture and for this reason it was pulp, and various carbohydrates.

In the powdered form diatomaceous ea sively as a filler or distributor in the ma number of products It is used in this manufacture of rubber articles, pla

blotting paper, linoleum, etc. Perhaps the greatest quantity is used as an extender in the manufacture of paints. Diatomaceous earth has the property of imparting "flatness" to paint surfaces without modifying the tints, and large quantities are used in the manufacture of undercoats for enamels, and for the white paint used for traffic lines upon tarred roads. Diatomaceous earth makes the paint more porous, thereby facilitating drying, and its chemical nature offers greater resistance to exterior conditions

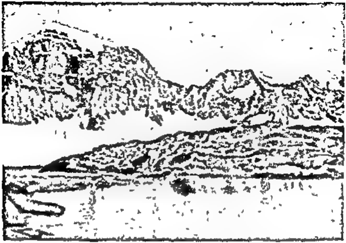
Building Materials and Abrasives

It has been claimed that as long ago as the sixth century B.C. the Greeks and Romans used diatomaceous earth as a building material, in order to decrease the weight of certain structures, and that in 522 A.D. blocks made from it were used to build the dome of the Church of Hagia Sophia in Constantinople. In modern practice it is usual to mix a small proportion of the earth with cement in order to increase the strength of concrete. From 2 to 4 per cent is the proportion usually employed. It is claimed that the strength of the concrete may be increased by 40 per cent in this way. The compressive strength of the concrete reaches a maximum after about three months ageing

Diatomaceous earth is used extensively as a mild abrasive. Incorporated in a variety of vehicles it forms an important part of many furniture creams, motor car polishes and household cleaners. Because of their different structure, diatoms from freshwater deposits are usually considered to be tougher and harder than those from Miocene marine deposits, and for this reason are preferred for the manufacture of metal polishes. Specially selected air-floated diatom material has been used with success in the manufacture of tooth pastes and powders, which owe their efficacy to the minute frustules of these marine plants.

Pharmaceutical Products and Cosmetics

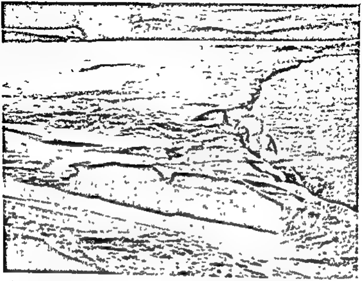
The practice of medicine calls constantly for research



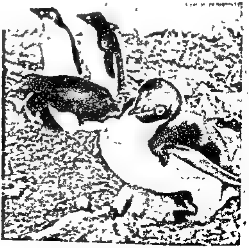
Two Antarctic Landscapes off the West Coast of Graham Land

1 Mount Luigi di Savoia du Fief on Goudier Islet, Port Lockroy

2 Mount William



3 At nesting time the penguins can be seen coming ashore along the fast ice edge of Hope Bay, Graham Land.

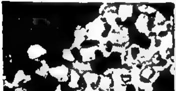


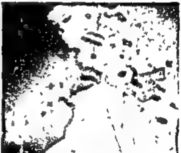
4. An Adelie penguin with chick at Hope Bay, Graham Land.

5 Flow curves on Glacier du Geant, Mont Blanc (Photo W Mittelholzer).

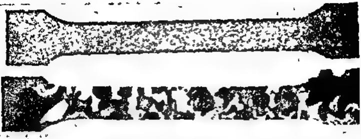
6 Crevasse in the Jungfraufirn taken from the bottom (Photo G Seligman).

7. Newly fallen snowflakes (Photo W. B. Bentley) Diameter about 1 mm

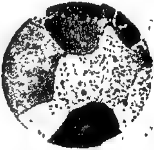




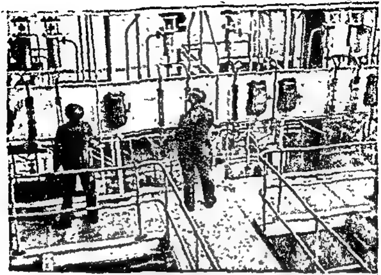
8 & 9 (*a*) Thin section of snow several years old, photographed between crossed nicols. This makes the crystals show up in bright colours. The blank regions are air spaces. (*b*) Thin section of glacier ice immediately below the firn line. The scale on both photographs is given by the teeth of the saw blade at the bottom which are 0.9 mm. apart.



10 Etched strips of aluminium before extension and annealing (top) and after (bottom), showing crystal growth.

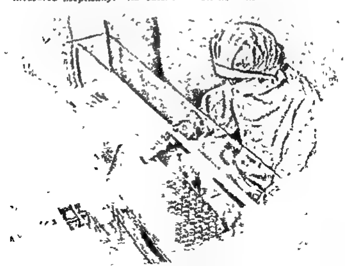


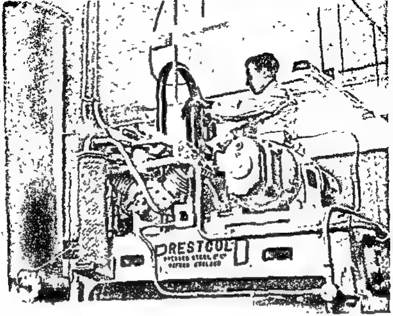
11 & 12. Thin sections of ice block between crossed nicols before and after plastic deformation by shear. Photo on right shows marked crystal growth produced by deformation (Photo H. Bader)



17 Next the culture fluid is extracted with amyl acetate, the two solvents flow down together, controlled by flow meters, and are separated by centrifuges below the platform (not shown)

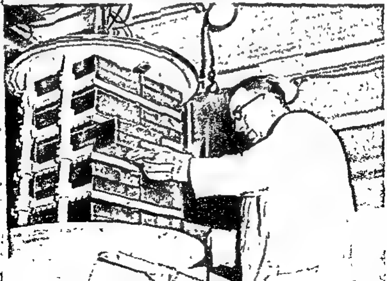
18 The purified concentrated penicillin solution is carefully measured aseptically, into batches of sterile vials

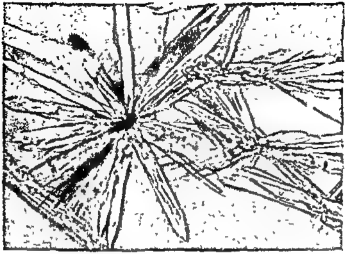




9 The batch of vials is placed in the container on the left of the .graph and frozen and dried by high vacuum pumps on the right

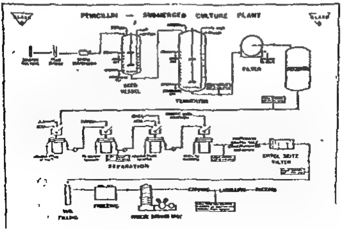
20 Loading vials into the container of plate 19 This process of freeze-drying converts a relatively unstable substance into a very stable one requiring no special storage conditions



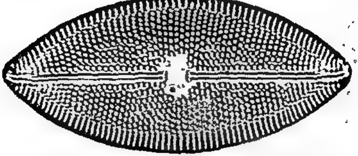


21 Crystals of pure penicillin

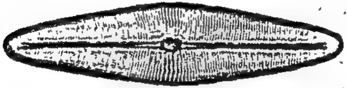
22. Flow sheet for Penicillin production



DIATOMS



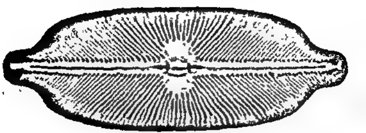
23 *Navicula granulata* A common diatom around the northern coasts of Britain



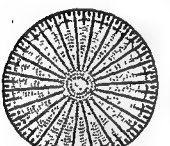
24 *Navicula Grevillei*

25. *Navicula crucigera.* Forms which live within a mucous frond very like a small seaweed.

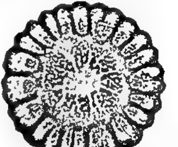
26 *Pleurosigma angulatum* This species is often used as a test object for microscope lenses. The lines on the surface are approximately 50,000 to the inch



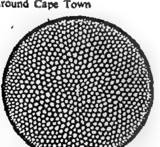
27. *Navicula humerosa.* Common around British coasts.



28. *Arachnoidiscus Ehrenbergii.* A handsome species, common around Cape Town

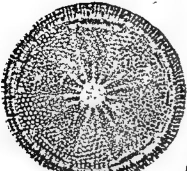


29. *Anthodiscus floreatus* A fossil diatom from New Zealand

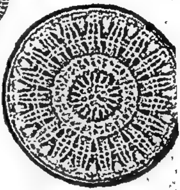


30. *Aulacodiscus tumulifer.*

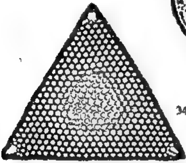
31 *Coscinodiscus radiatus* common species in the Sea plankton



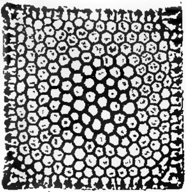
32 *Actinoptychus heliopelta.*



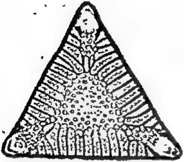
33. *Lepidodiscus imperialis* Fossil species of exquisite design



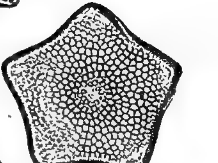
34 *Triceratium favus.*



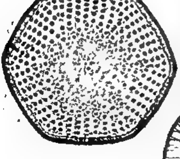
35. *Triceratium favus* var. *quadrate.* Fossil species from New Zealand; the former is common in the North Sea as a living species



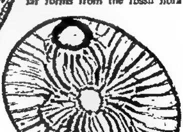
36. *Triceratium Morlandii.*



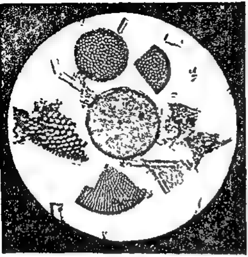
37. *Triceratium cyclamen.*



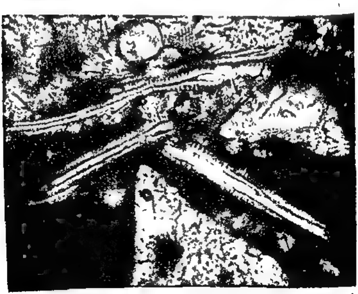
38. *Stictodiscus hexagonus* Angular forms from the fossil flora



39. *Auliscus caelatus.* A living species from the Mediterranean.



40 Diatoms recovered from one of the filtering elements of a "Metafilter"



41. Jutland kieselguhr or "molera," used in the manufacture of refractory bricks, showing diatoms in transverse section, embedded in a siliceous matrix

into the use and application of a wide range of substances.' In the treatment of many skin diseases a chemically inert base is required to act as a diluent for potent medicaments, and one of the most successful is prepared diatomaceous earth. Specially selected material of the highest quality is used to carry such substances as ichthyol, resorcin, mercurials, benzoates and salicylates for the relief of the strange and distressing skin affections so common in tropical countries. The modern craving for glamour, particularly the kind which comes out of a box, provides many uses for diatomaceous earth. In the manufacture of face powder, it is perhaps one of the most suitable substances. Its high absorptive properties make it an excellent carrier for the various pigments which impart the all-important "shade" to the product, and provide a most suitable vehicle for the perfume which is said to convey such "allure" and "mystic charm".

Stratigraphic Importance

From a geological point of view, diatoms provide much interesting information. Diatoms fossilise easily and persist throughout geological time showing little or no signs of decay, and provide an indelible record of the past history of the earth's crust. A close study of the type, structure, abundance, and position of the diatoms in the strata provides data to the field geologist concerning climatic conditions, the degree of alkalinity or acidity, salinity and pH of the water in which they lived millions of years ago.

The close proximity of some of the largest deposits of diatomaceous earth to oil-bearing strata of the same or a closely related geological age, particularly in California, led to the belief that the diatom was in some way responsible, in part at least, for the occurrence of the oil, and it is now accepted by a large number of experts that the asphaltic oils from Miocene strata most probably were derived from this source.

Medical Front

Rh Factor

ONE of the big advances in medicine in the last twenty years has been the growth in our knowledge of blood diseases. The symptoms of anaemia, lack of red blood, are now known to arise in one of three sorts of ways – through nutritional deficiency (e g , lack of essential dietary iron) or failure of the bone marrow to make red cells, through bleeding, through excessive internal destruction of red cells (haemolysis) Some diseases are characterised by destruction of red blood. malaria is one such. If the destruction is very rapid, the red pigment (haemoglobin) set free in the body is not removed quickly enough and lingers for a time in the skin and eyes as a yellow colour—one of the origins of the symptom of jaundice. When blood of a wrong (incompatible) group is given in a blood transfusion, the unsuitable red cells are clotted together and broken by agglutinins in the patient's circulation, and the liberated colour may cause a transient yellow.

Jaundice in the newborn child has been recognised as a distinct, puzzling, disease since about 1902 when a Birmingham doctor reported "a family series of fatal and dangerous cases of jaundice of the newborn—fourteen cases in one family, with four survivors". This report was followed by others from various physicians, for instance from another Birmingham man came "A series of fatal cases of jaundice in the newborn occurring in successive pregnancies". As time passed and knowledge extended, it became clear that one of the causes of the death of the unborn child within the womb was this same condition with the symptom of jaundice. Sometimes it caused illness or even death after birth, sometimes if more severe it killed before birth. Further, it seemed to get worse and worse in a series of

pregnancies in one mother. Her second child, shall we say, would have severe jaundice but live, her third be born prematurely and perhaps die, her fourth be a real miscarriage, and her fifth pregnancy collapse when barely half completed.

The causes of jaundice are many. However, after thirty years of study it became clear that this jaundice of the newborn is due to haemolysis, something destroys the infant's red cells, and this poison is the cause of all the trouble. But what sort of a poison it could be, and where it was coming from, seemed for the time an insoluble question.

As so often happens, the answer came from research along a slightly different track as the result of a chance observation. In 1939 two American doctors gave the mother of a still-born child a blood transfusion of her husband's blood, and noticed a severe reaction. Although husband and wife both belonged to Group 0, the husband's blood upset the wife, and very careful test showed that her serum in fact agglutinated his red cells. This observation led them to suggest rather brilliantly that the mother had become immunised against a new red cell antigen or blood group substance possessed by her dead child who inherited it from her husband. The following year, a world authority on blood groups, an Austrian doctor working in New York, tracked this new red cell antigen down.

He had been studying the relationship between human and monkey blood groups—which, incidentally, is one way of finding out which monkeys are our closest cousins. He prepared antibodies (by injection into guinea pigs and rabbits) to the red cells of the Rhesus monkey. That is to say, something in the blood serum of the injected guinea pig would now agglutinate and haemolyse Rhesus red cells These antibodies were now tested against the red cells of humans—normal American white people, and it was found that 85 per cent of those tested were like the Rhesus monkey: their red cells also agglutinated, and therefore contained a similar blood group factor to the monkey.

They were therefore called Rh-positive. Like other blood groups, it is inheritable.

The explanation of jaundice of the newborn is now clear. The father is Rh positive, the mother Rh negative. The child inherits the Rh factor from its father, and starts to give its mother Rh antigen She forms antibodies to this "foreign" blood group substance, which go back to the child and destroy its red cells. Research in the last four years has confirmed, but complicated the picture. There is not *one* Rh, but several, the process is controlled by at least three inheritable genes.

For practical purposes, however, the explanation is adequate to forewarn the ante-natal clinic. The coming of the illness can be predicted and watched for. If necessary, the birth of the child can be brought on a month early, to lessen the danger from the mother's antibodies. But the research is not over, for we cannot yet prevent the disease. The mortality is perhaps 30 per cent instead of 50 per cent as formerly, an improvement certainly, but in time Science will do better.

Skin Disease and Psychology

Dr. G. G. Robertson has published several papers on the relation between ill health and mental outlook. The latest of these contributions to what is sometimes grandiloquently termed "psychosomatic medicine" appeared in the *Lancet*, July, 1947, and deals with dermatitis. He reminds us first of the case of Job, reported in the Bible. Job was a very rich man who regarded his wealth as the just reward for leading an upright and honest life. When his flocks and herds were stolen, his crops burnt, and his seven sons and three daughters killed by a whirlwind, he could not understand why apparently God had forsaken him. All his life he had walked in the ways of the Lord, and wealth had been his just reward; but now, inexplicably, it was gone. It was beyond his comprehension and his body began to itch and ooze intolerably.

Dr. Robertson quotes a number of similar cases from his own practice, where apparent injustice coincided with the onset of an intractable skin disease. A girl who had worked for five years in a tobacco factory got a dermatitis of her hands, which would not clear up. Enquiry demonstrated that the illness began when her forewoman had taken an unreasonable dislike to her and begun to make her life a misery. She was transferred to another department of the same factory, handling tobacco as before, and the skin then got better in a few days. A man was taken from his own work and sent to a shipyard by the Ministry of Labour, and it *seemed to him that the only reason for this* change was the pleasure minor civil servants got out of wielding their authority and pushing workers about. Within two months he got a cut on his leg which would not heal, and a dermatitis above it, which would not respond to treatment, until he returned to his old job, when it all got better.

It is important not to make the mistake in cases of this type of supposing that the illnesses were somehow deliberately brought on by the patients, who did not wish to get better. Quite the reverse was the truth, but the skin illness appeared to arise under the stress of deep grievance, and to get worse as the emotional difficulties were enquired into and brought out. When the grievance was remedied, or the patient realised the connection between his grievance and his illness, he got better.

We know little, scientifically speaking, about the relations between emotion and illness, and what we know is really old knowledge, like the case of Job. But it has got forgotten under the spate of new drugs and new physiology, and only now is being rediscovered and re-developed, as our full ignorance is realised.

How Penicillin Works

Every day, in hospitals and clinics all over the world, millions of units of penicillin are used to treat disease: yet nobody knows how the drug acts. It is a fact that it kills

certain sorts of disease bacteria (Gram-positive organisms such as streptococci and staphylococci), but the precise way it initiates the irreparable disorganization we call death is still unknown.

This is not for want of laboratory study, which has clarified the problem a little, recently. One can watch under a microscope what happens to a bacterial cell after treatment with a drug. One can measure its respiration, or power to ferment or digest foodstuffs, or its growth rate, or reproduction by division into two cells, before and after treatment with penicillin. All this has been done, and two facts, but only two, emerged. The first was that penicillin does not harm resting cells As long as the living bacteria are just "ticking-over", respiring, growing a little perhaps, but *not dividing*, they can go on living. Penicillin somehow steps in when they divide. And that is the second fact: as soon as they have divided in the presence of penicillin, they are doomed Wash all the drug away and give them a rich nutrient medium—it makes no difference; somehow the damage is done and they must all die. But the direct experimental approach has been of no further help. These doomed cells, although in some way changed by the penicillin, continue to respire, digest, grow normally for a time, and then slowly decay and dissolve. The immediate change wrought by the antibiotic has not been detected.

That at least was the picture until recently, when Dr. E. F. Gale and his co-workers at Cambridge while pursuing another line of work made an interesting relevant discovery. They have been studying for some years the chemical changes bacteria can produce in amino-acids, the component parts of the proteins of protoplasm. First they studied the different ways the bacterial cells broke down or digested these amino-acids, and then they used their new knowledge to begin the more fascinating problem of how the amino-acids are joined together by the cells to make proteins; or in other words, how living things make their own protoplasm.

They chose to study one single amino acid at once, so as not to complicate the results, and they chose glutamic acid because it was easy for them to measure it. One of their first discoveries was that some bacteria accumulate a great reservoir of free glutamic acid inside their cells, and then slowly draw on this store for building protoplasm and other uses. Even though there is only a very dilute solution of glutamic acid in the medium outside the cells, they are able to snap it up and get a very strong solution inside. Out of interest they did experiments on a great range of different sorts of bacteria, and found that it was only the Gram-positive organisms which show this glutamic acid concentration and store. It is also the Gram-positive organisms which are killed by penicillin Was there a connection between the two facts?

There was. Bacteria treated with penicillin can no longer snap up glutamic acid and make a store Once they have divided, no more amino-acid comes in, and they must live on this reservoir alone. Gradually that level drops, until finally there is insufficient to support further life, and the cell dies, from the effects of glutamic-starvation so to speak.

So this has pushed a little nearer that mysterious first effect of penicillin which is the fundamental one, and still undiscovered. How the cell manages to accumulate its glutamic pool has been the new point of laboratory study, and although a great deal of the mechanism is now known, none of it is affected by penicillin. The subtle piece of the living cell that is changed by the drug has not been tracked down after all Perhaps the effect on glutamic acid accumulation is not so near the heart of the matter as was hoped, but it still seems a good lead. At the same time, we have to remember that at the time of writing (September, 1947), a great many more changes and events occur from moment to moment inside a living cell than we know how to observe or measure. Glutamic acid metabolism is only one facet of life. Penicillin may really be striking elsewhere.

Food for Thought

Glutamic acid is much in the scientific news. In bacteriology, one interesting discovery is that the capsule around the Anthrax bacillus, which probably protects the germ from the body's defences, and so makes it a disease-producer, is chemically a polypeptide composed *entirely* of glutamic acid molecules, linked together or polymerised into very long molecular chains. A chemical substance of this particular nature has never been known before. In experimental psychology, it is claimed that rats given liberal amounts of glutamic acid in their food become much more intelligent than the average run of rats in learning and solving the way out of mazes. It is suggested that they do not get enough of this normal food component, present in all meat and protein foods, in the stock diets, and consequently cannot think so well. Certainly glutamic acid has some important but unknown role to play in the chemistry of the brain. According to a recent result the brain can manage with less sugar (glucose) if given glutamic acid as well—and if this is true it is the only substitute known.

These results with rats, and other researches, have, encouraged doctors to try to *improve the intelligence* of children in the same way, and to try to control epilepsy (petit mal) with doses of the amino-acid. Preliminary results are encouraging, but sceptics will point to the long list of past epilepsy cures, boosted for a time and then discarded. There are years of work still ahead. We must know a good deal more about glutamic acid and why it is so important. We have only got to the threshold of knowledge so far.

Glaciers

BY DR. M. F. PERUTZ

ABOUT one tenth of all the land surface of the globe, comprising almost six million square miles, is permanently covered with ice. If all the ice in the polar regions melted and flowed into the oceans, the sea would rise by about 150 feet and submerge a large proportion of the fertile land on this earth. Without the steady flow of meltwater from the Alpine glaciers which act as tremendous reservoirs, the levels of some European rivers might be subject to violent fluctuations, with the result, for instance, that many hydro-electric power stations might have to be idle for a large part of the summer, unless huge artificial reservoirs were constructed.

Interest in glaciers in the past, however, has owed little to utilitarian motives, and most of the men who explored them have been enthusiastic amateurs, attracted by love of adventure and the beauty of the mountains. The beginning of interest in glaciers coincided with the growing consciousness of Nature during the 18th century, and was at first confined to naturalists who lived in the Alps, at a time when travellers from the lowlands still regarded the mountains as a horrible and fearful wilderness. One of the first to bring glaciers to the attention of the educated world was Horace-Benédict de Saussure, Professor of Philosophy at Geneva, in his charmingly written *Journeys in the Alps* which appeared in 1779.(1) During the 19th century, observation of the glaciers developed hand in hand with the exploration of the Alps by mountaineers and scientists, but experimental work involving accurate measurements did not get into its stride until the 1880's, when the first text-book of glaciology also made its appear-

tell of people who vanished in them, never to be seen again Actually the depth of crevasses in the Alps does not seem to exceed 100 feet and is usually very much less, while the total depth of Alpine glaciers may be of the order 1,000 feet or more (2,700 feet has been recorded in one locality). The lack of sounds from objects dropping into crevasses is often merely due to a deep layer of soft fluffy snow covering the bottom (Plate 6)

The frequency of crevasses is closely related to the speed of glaciers which in turn is a function of their size and slope. Thus the Upernivik Glacier, one of the gigantic ice-streams emerging from the Greenland ice-cap, advances at times by 125 feet per day, which is as much as a smaller Alpine Glacier covers in a whole year. Owing to their great speed, the surfaces of some of the large glaciers in Greenland and in the Himalayas are riddled with crevasses and broken up into seracs (ice-towers) to a degree that makes human progress over them exceedingly slow and tedious. This relationship between the frequency of crevasses and the speed of glaciers can readily be understood, since it was found that any increase in absolute speed also increases the differences between the relative speeds of different parts and hence magnifies the stresses on the glacier surface.

In part, the great velocities of the Greenland glaciers are probably due to their ending in the sea, where they can flow free from external friction. On the other hand, if glaciers approach the sea at a steep slope and with high velocity, their buoyancy gives rise to stresses large enough to cause the sudden fracture of enormous ice-walls which collapse and split up into fragments amid thunderous noise and great eruptions of spray. These fragments then drift into the ocean as ice-bergs. All ice-bergs, in fact, originate from glaciers, and most of those in the North Atlantic come from Greenland, but fortunately only a small proportion of the 130 cubic miles or so of ice-bergs which that sub-continent annually produces ever reaches the shipping lanes.

Advance and Recession

Glaciers are rarely in equilibrium—the annual accumulation of snow hardly ever exactly balances the loss of ice through evaporation and melting. Usually either the one or the other factor predominates, and as a result the glacier-end either advances into the valley or recedes from ground formerly occupied. Large advances and recessions of the order of miles usually take years or even decades and are the results of long-term climatic changes, but small fluctuations of the order of 100 feet may occur in any year for no apparent reason. Sometimes one glacier advances and another in a neighbouring valley recedes during the same period, and in single seasons such variations can often be attributed to slight differences in the local distribution of snowfalls. At present, however, the great majority of glaciers all over the world are going through a period of rapid recession and many smaller ones are dwindling away, a phenomenon which will be discussed in greater detail in the section on glaciers and climate.

At this stage we are more concerned with the actual mechanism of advance and recession than with the climatic changes which cause them. A surplus of snow accumulation and a consequent increase in the thickness of the glacier may result in a gradual increase in the velocity of flow, followed by an advance of the glacier-end. Sometimes, however, events take a far more spectacular course. It appears that some glaciers do not at first react to a gradual increase in thickness, which may continue for a number of years without being accompanied by a corresponding increase in velocity. Then, suddenly, the pent-up masses of ice break out and form something like a tidal wave which propagates itself along the glacier, causing an enormous increase in the velocity of flow. In the case of one glacier in the Tyrol, for instance, Hess calculated that the total thickness of the glacier at the crest of the tidal wave had not risen by more than a quarter, yet the motion of the glacier had been speeded up by a factor of 16. On such occasio

was to be followed by shear along the crack and healing of the crack through regelation. The various schemes differed in points of detail, but none of them proved entirely satisfactory. We can realise to-day that it would have been impossible in the middle of the last century to furnish a better explanation for the plasticity of ice, considering how little was then known about the nature and physical properties of crystals in general. At the time, however, people were sometimes less conscious of the weaknesses of their own theories than of those of their colleagues, and as a result they engaged in a series of violent disputes. Thus Tyndall, in his book *Glaciers of the Alps* contains a critical examination of the theory of James Thomson, brother of Lord Kelvin, with the none-too-flattering comment:

"In short, this theory, as it presents itself to my mind, is so powerless to account for the simplest facts of glacier motion, that I feel disposed to continue to doubt my own competence to understand it, rather than ascribe to Mr. Thomson an hypothesis apparently so irrelevant to the facts which it professes to explain."[40]

Gliding and the Atomic Structure of Ice

In 1888 McConnel and Kidd made a discovery which seemed, at least *temporarily*, to resolve the [illegible] the theory of glacier flow. They found that the ice yielded plastically to shearing stresses, even at temperatures far below the melting point, provided that a component of the stress was parallel to the plane of the original water surface. Though the important bearing of this experiment on the mechanism of glacier motion was appreciated at the time, its full significance did not become clear until years later, when W. H. Bragg and W. H. Barnes determined the arrangement of water molecules in an ice crystal with the help of X-ray analysis.

The simplest form of ice crystal is a prism with a hexagonal base, as shown in Fig. 64. In order to

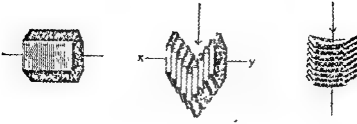


Figure 6

(a) Hexagonal ice crystal

(b) Crystal deformed plastically by shear stress parallel to hexagonal base showing idealised picture of glide planes.

(c) Elastic deformation of crystal by shear strain normal to glide planes In lake ice glide planes are parallel to the water surface

arrangement of the water molecules this picture has to be enlarged approximately 1,000 million times. This has been done in Fig 7, where the water molecules in the crystal are seen to be arranged in a regular pattern, and to be grouped together in layers which are parallel to the hexagonal base of the crystal. If a shearing stress is applied to such a crystal parallel to its base, the layers of molecules begin to slip over each other and, as a result, the entire crystal is deformed in the manner shown in Fig. 6b. This shearing of crystals parallel to definite planes is known as *gliding*, and the crystal planes involved are known as *glide planes*. Gliding is liable to occur in any crystals where the atoms or molecules are grouped together in layers. Since, this is very frequently the case, particularly in metals, gliding is a property of great technical importance.

McConnel and Kidd's results on gliding in ice crystals were eagerly seized upon by several glaciologists and used as a foundation for improved theories of flow. Even so, the amount of knowledge available at the time as to the

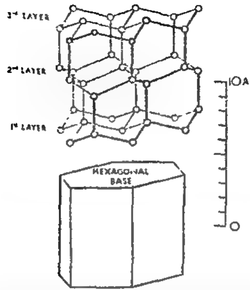


Fig. 7.—Crystal structure of ice. The lower part of the figure shows the outlines of a small ice crystal—in fact the smallest that could exist—and the upper part shows the arrangement of the water molecules within it. The molecules are represented as circles and the bonds between them as straight lines. To give the picture perspective the molecules facing the observer have been drawn in bold lines. The divisions of the scale are in Angstrom units, i.e., in 100-millionths of a centimetre.

plasticity of crystalline solids was insufficient for the formulation of a consistent theory. The inevitable contradictions and loopholes which these older theories entailed were partly responsible for the division of glaciological opinion into two rival schools of thought whose opposed and apparently irreconcilable views have dominated the glaciological literature until very recently. One school maintained that glacier ice is essentially plastic and that the differential movement observed in glaciers is effected through glide in individual crystals, accompanied by the growth of cry-

through the exchange of molecules across their boundaries. The other school fixed its attention—somewhat too exclusively—on certain systems of stratification bands which are commonly observed in glaciers and which they regarded as evidence for the existence of large-scale thrust planes. According to this school differential movement in the glacier proceeded through the spasmodic motion of rigid masses of ice over extensive thrust planes which take the form of cracks in the ice, and later, through regelation, develop into stratification bands.

The conflict between these two theories was finally resolved by the more powerful methods of observation and refined experimental techniques brought into the field by Seligman's Jungfraujoch Research Party in 1938.

RESULTS OF MODERN RESEARCH

The Jungfraujoch Research Party, of which I was fortunate to be a member, started its work with the immense advantage over all previous investigators of having its base at the International Research Station on the Jungfraujoch; being situated at the source of the Great Aletsch Glacier, this station offered ideal facilities for work on glaciological problems. Initially our programme was more concerned with the transition of snow into glacier ice than with the actual mechanism of flow.

Transition of Snow into Ice

The delicate lacework patterns of newly fallen snow crystals have always been the delight of nature observers and amateur microscopists, and have even served as a basis for mystical hypotheses on the geometry of the universe and the fundamental pattern of life. Plate 7 shows three particularly beautiful specimens among some thousands of snow flakes photographed in the course of a life-long study by W. A. Bentley of Jericho (Vermont).

A few days or weeks after it has fallen, snow presents an entirely different aspect. The fine needles, sharp corners

and plane faces, indeed all signs of regular and symmetrical growth, have disappeared and given way to rounded granules of considerably larger size, forming a loose conglomerate. A thin section of such aged snow is shown on Plate 8. For the first few years of their life in the firn region, these crystalline granules change little in size, but when the crystals finally emerge on the surface of the glacier tongue after having been buried for several decades or even centuries, they have grown to about a thousand times their original volume, have lost most of the air that was enclosed between them and have become firmly interlocked (Plate 9) [5]

This metamorphosis of snow into glacier ice presented an interesting physical problem as such and was soon found to be closely related to the more general problem of glacier flow. In order to study this relationship more closely, we lowered ourselves into some of the deepest crevasses on the Jungfraufirn, cut samples of ice from their walls at different levels and examined these under the petrological microscope. The microscopic work was carried out in a laboratory which had been hewn out of the stationary ice on the Jungfraujoch and which kept a reasonable constant temperature of —4° C.

As a result of our research, and of subsequent experiments carried out by British, Swiss, and American workers, it has now become clear that the flow of glaciers and the growth of the crystals are analogous to similar phenomena in metals, with which scientists have long been familiar.

Creep

Differential flow in a glacier is due to the slow deformation of ice under the influence of sustained stresses. Such deformation is known in metallurgy as creep Its physical mechanism is complex and can only be explained here in very general terms. Fundamentally, it is due to local re-arrangements of atoms in the crystals, leading either to the deformation of individual crystals by gliding or to

transfer of atoms across their boundaries The rearrangements of the atoms are activated by their thermal energy, i.e., the external force produces a deformation by giving a preferential direction to the otherwise random thermal movement of the atoms. A rise in temperature accelerates the creep rate by increasing the number of local rearrangements taking place at any given instant.

The creep properties of ice itself are still largely unexplored, but those of many metals are to a certain extent known, and can be applied to ice in a qualitative way. It will be useful first to describe some of the fundamental laws of creep and then to consider how they help us to understand the flow of ice in glaciers.

(1) If the temperature of an ice block is kept constant and the external force is varied, the creep rate will not vary as a linear but as an exponential function of the applied force. This means, for instance, that if an increase in the shear stress from 50 to 60 lb./sq. in. doubles the creep rate, an increase from 100 to 120 lb./sq. in. may quadruple it, an increase from 150 to 180 lb./sq. in. may multiply it eightfold, etc. In other words, the plasticity of ice increases rapidly with the applied stress.

(2) Below a certain stress, creep will not take place at all, and the deformation produced by an external force will be purely elastic. This minimum stress is known as the yield stress.

(3) At a given stress the creep rate of ice depends on the temperature. The closer the temperature approaches the melting point, the greater the creep rate. It was found in laboratory experiments, for instance, that at a certain stress the creep rate of ice at —1° C. is 1,000 times greater than at —20° C. This means that ice becomes increasingly rigid at lower temperatures.

Besides temperature and applied force, there are several other factors which influence the creep rate of ice, but none of these need be elaborated here, and we can now proceed to consider how the laws of creep which have just

been outlined could serve to explain the plasticity of ice in glaciers. First of all they show that no special mechanism —such as regelation—need be invoked to explain the existence of streaming motion in glaciers, since ice is only one among many other apparently brittle crystalline materials which can be deformed plastically by creep under suitable conditions. In addition, many of the more puzzling characteristics of glaciers can be understood in the light of the general rules set out above. Consider, for instance, the relation between creep rate and applied force. It has been mentioned that the large Greenland glaciers sometimes flow more than a hundred times faster than the smaller Alpine ones, although the difference in thickness may not amount to more than a factor of three or four. Such extraordinarily rapid flow is to be expected in view of the exponential relation between creep and applied force. It will be remembered also that in one instance an increase in the thickness of a glacier by only a quarter accelerated its flow by a factor of 16, thus giving rise to a rapid advance of the glacier-end. Obviously this is only another manifestation of the same mechanism. Seasonal variations in the flow velocity of the firn region where glaciers have recently been found to move twice as fast in winter as in summer are probably due to the same cause, the increased winter velocity being the reaction of the glacier to the weight of the newly deposited snow cover.

The existence of a yield stress below which creep does not occur explains the presence of crevasses as well as their limited depth. In theory, cracks in the ice might be produced at any depth, but no cracks in the interior of the glacier would be able to persist, since they would soon be closed by creep under the pressure of the overlying ice masses. As we approach the surface, however, a critical depth will be reached where this pressure becomes smaller than the yield stress of ice; above this critical depth cracks in the ice could persist indefinitely, while below it they would be closed through creep. In actual fact the limiting

depth of crevasses is not as sharply defined as this statement would suggest, since the rate of opening of a crevasse may often be faster than the rate at which creep tends to close it in its lower reaches, so that for a time, at least, the real depth may be considerably in excess of the critical depth as determined by the yield stress.

The last of the three laws mentioned above related to the influence which temperature exercised on the creep rate. This is comparatively unimportant so far as Alpine glaciers are concerned, because practically their entire mass is always at the melting point of ice. In polar glaciers, on the other hand, temperatures vary at different depths, and the increasing rigidity of ice at temperatures below the melting point profoundly affects their behaviour. This point will be discussed in greater detail in the section on ice caps.

Annealing and Crystal Growth

In metals the heating or *annealing*, as it is called, of a cold-worked specimen is accompanied by an increase in the average crystal size, due to the growth of some crystals at the expense of others Conditions prevailing in a streaming glacier are analogous to those in a metal undergoing deformation above its annealing temperature This may account for the very large increase in the average crystal volume which accompanies glacier flow. Plate 10 illustrate this analogy by showing a strip of aluminium in which extension and subsequent annealing produced a striking increase in crystal size, and sections through a block of ice in which a more moderate but still very marked crystal growth resulted from plastic deformation by shearing.

What determines the growth of one crystal at the expense of another? In order to understand this process, we have to consider the thermal motion of the water molecules at the boundary between two ice crystals At temperatures near the melting point there will be a continuous and rapid exchange of molecules between the two crystals; if both crystals are at the same temperature and free from strain,

the number of molecules migrating from crystal A to crystal B will be the same, over a period of time, as the number migrating from B to A, so that the volume of each crystal will remain unchanged. This state of equilibrium can be upset by making the energy content of the two crystals unequal. For instance, if the temperature of crystal A is raised relative to that of B, more molecules will migrate from A to B than in the opposite direction, with the result that B will grow at A's expense Another way of raising the energy content of a crystal is to strain it elastically. Therefore, the effect of straining A more than B will be exactly the same as that of making A warmer than B, i e., it will lead to the growth of B at the expense of A.

In a glacier, therefore, an increase in the average crystal size is likely to arise as a result of variations in the energy content of neighbouring crystals. This could be brought about in different ways, of which the simplest is probably this: Suppose two crystals A and B are in contact and are both subjected to the same shear stress, but the orientation of crystal B is such that its glide planes are parallel to the direction of stress, while those of A are normal to the direction of stress (see Fig. 6b and c) In that case B will be free to yield to the stress by gliding while A will undergo elastic strain Thus A will have a greater energy content than B; this will lead to the growth of B at A's expense and eventually to the complete disappearance of A.

The example just given can be generalised in the statement that different orientation of crystals relative to the external stress leads to the growth of some crystals at the expense of others. This is due to the anisotropic character of the crystals themselves, i e., the dependence of their mechanical properties on the direction in which an external stress is applied.

Present Views on Glacier Motion

We have seen in the foregoing pages how each adv in our knowledge of the fundamental properties of so

matter has led in turn to a clearer understanding of the nature of glacier flow. To-day the "fluidity" of ice which used to mystify the early observers is seen as a natural consequence of the creep of ice under the influence of sustained stresses, and creep itself is known to be the outward effect of a multitude of atomic rearrangements which are activated by thermal motion. The stresses set up in the individual ice crystals during creep give rise to small differences in their energy content which are now recognized as the ultimate cause of the striking growth in the average crystal size during flow (Plates 11, 12).

The motion of rigid masses of ice over large-scale thrust planes to which some observers had attached such exclusive importance exists, but may be regarded as a subsidiary rather than a primary factor in the mechanism of flow. It does not necessarily take place along actual cracks in the ice, but preferably along bands of large crystals which are oriented with their glide plane parallel to the planes of shear.

Temperature Distribution in a Glacier

It has long been known that Alpine glaciers are at the melting point of ice, except for an insignificant surface crust which is affected by external temperature variations. This may seem puzzling, because the mean annual temperature in the upper regions of Alpine glaciers is usually far *below* 0° C., and also because a glacier at or near 0° C. might be expected to melt away under the influence of the heat of the earth.

The clue to the thermal behaviour of glaciers is to be found in the very large difference between the specific and the latent heats of ice (0.5 as against 82 calories); so great is this difference that the heat liberated on freezing 1 gramme of water (the latent heat) is sufficient to raise the temperature of 160 grammes of ice by 1° C. Or, looking at it in another way, very little heat is needed to raise the temperature of an ice block from —1° to 0° C., as compared

to the heat required to turn the same ice block at 0° C. into water at 0° C.

Consider the firn region of a glacier at the end of September when its entire mass is known to be at the melting point. At the onset of winter a new layer of snow will be deposited and at the same time a wave of cold temperature will slowly sink into the glacier. The thermal conductivity of the new snow layer and of the layers of snow deposited in previous years is so poor that the winter cold wave does not penetrate further than about 50 feet below the surface. In spring the snow at the surface begins to melt, and the meltwater trickles down through the porous snow, re-freezing on reaching the colder layers below. The heat which the meltwater liberates on re-freezing is sufficient to bring all the snow back to the melting point and thus to wipe out the entire effects of the winter cold wave before the end of June. This is what happens in the firn region. In the glacier tongue the winter cold wave travels less far, on account of the higher temperatures prevailing in the valleys, and in spring its effects are very soon obliterated by the heat of the sun which penetrates sufficiently deeply into the clear blue ice to warm it up to melting point.

It can be shown on theoretical grounds that, even if surface melting were entirely absent, the flow of heat from the interior of the earth would warm up most of the glacier to the melting point, owing to the relatively small specific heat of ice. The latent heat of ice, on the other hand, is so great, that the heat of the earth does not melt more than a layer half an inch thick from the bottom of a glacier in a whole year.[6]

It should perhaps be pointed out that although the bulk of the glacier is at the melting point of ice, this does not imply that it is exactly at 0° C. It will be remembered that the melting point of ice is reduced by 0.0075° C. for every atmosphere of hydrostatic pressure. Ice in the interior of a glacier will, of course, be under a pressure correspc

One of the most important findings of the Wegener expeditions concerned the economy of the ice cap. Their problem was to decide whether the ice cap is largely a stagnant mass of dead ice, built up in some previous age when snow falls were more abundant than they are now, or whether the ice cap is being nourished by regular falls of new snow even to-day Sorge, one of the members of the expedition, dug a deep shaft in order to measure the thickness of successive layers of annual snow accumulation and found this to amount to an average of 34 inches of snow, corresponding to a height of over 12 inches of water

Sorge's data at first sight seemed to suggest that the ice cap is continuously getting thicker, which is hard to believe. An alternative explanation offers itself if the ice cap is regarded as a vast mass of plastic material sagging under its own weight. The precise mode of sagging will be determined by the creep properties of ice, i e., by its rate of creep at a given load and temperature, which have yet to be measured. The general type of behaviour, however, can be predicted from the laws of creep which have just been explained: the increase of plasticity with rising load, its decrease at negative temperatures and the existence of a yield stress.

The temperature in the Greenland ice cap rises from —30°C. at the surface to the melting point some thousands of feet below. Hence we should expect the ice cap to be comparatively rigid in its upper layers and to become increasingly plastic at greater depths, since the creep rate is likely to rise with depth both as a result of the increasing weight of the overlying layers of ice and of the rising temperature. These considerations led to the prediction that the sagging movement of the ice cap is likely to produce internal currents of ice flowing from the centre towards the margins of the ice cap The currents should be fastest in the neighbourhood of the rockbed and slow down gradually with increasing height; their velocity probably becomes negligibly small as soon as temperatures below the melting point are reached.

which are most easily ascertainable, partly with the help of old documents and drawings and partly from the evidence of moraines. The most recent advances took place towards 1750, 1820, 1850, and from about 1885 to 1895. Since then glaciers all over the world have gone through a period of recession which has assumed an increasingly rapid pace since 1930. No accurate measurements are needed to observe this recession. It can be seen by anyone visiting some of the hotels which were built in Switzerland towards the end of the last century for the purpose of offering the traveller a comfortable close-up view of those supposedly inaccessible wastes of ice. In many of these places the glacier has now disappeared from view, so that the names of the establishments (Hotel Gletscherblick, etc.) appear as much out of keeping with the times as their Victorian architecture. More serious than the fading attractions of these tourist resorts is the reduction in water supplies for hydro-electric power which the glacier recession threatens to bring about.

The recession of glaciers in the Alps is part of a worldwide phenomenon which is manifesting itself in a variety of ways. In the Northern hemisphere glaciers in Greenland, Spitsbergen, Iceland, and Scandinavia have all been affected; those in Southern Norway are thinning so fast that their complete disappearance seems not improbable. At the same time the border of the Arctic pack-ice is receding northwards, so that the coal shipping season in Spitsbergen, for instance, now lasts for 230 days out of the year, as compared with an average of 95 days in 1909-12. In Northern Russia the line of permanently frozen ground has receded in some places by as much as 25 miles, thereby opening up large new areas to cultivation. A marked retreat of the pack ice has also been reported from Antarctica.

What are the causes of glacier variations? They may be due to changes either in atmospheric temperature or in the total impact of radiation (which is partly associated with the intensity and variation of sunshine) or in the annual precipitation of snow. The Swedish glaciologist Ahlmann and

tiennent aucun registre, a pu facilement trouver créance dans leurs esprits."[1]

Conclusion

Glaciers may be shrinking, but interest in them is still expanding, as shown, for instance, by the recent formation of a British Glaciological Society. The execution of glaciological research has been helped by recent governmental and political interest in the polar regions, but the impetus behind this renewed activity is still due to the purely academic interest which the intricate problems of glacier flow have for the physicist and geomorphologist. Although most glacial phenomena can now be explained in a qualitative way, we still lack a precise correlation between the plastic properties of ice and its behaviour as a mass, and much research will be needed before it will be possible, for instance, to predict the flow properties of a glacier from the dimensions and inclinations of its bed or to account for many of the facts of glacial erosion. Some of the research now being initiated in this country and elsewhere may help to elucidate these problems.

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(6) Hughes, T. P., and Seligman, G. *The Temperature, Melt Water Movement and Density Increase in the Névé of an Alpine Glacier*. Mon. Not. Roy. Astr. Soc. Geophys. Suppl. Vol. 4, p. 616, 1939

(7) Ahlmann, H. W., sen., "Researches on Snow and Ice, 1918-40," *Geogr. Journ.* Vol. 128, p. 11, 1946

For a general, short and lucid account of glaciology, see Meinzer, O. E., *Physics of the Earth* Vol. IX Hydrology. Chapter on *Glaciers* by F. Matthes. McGraw-Hill Book Company, New York, 1942

purpose, it appeared in Germany as in the United States that the necessary first step would be the laborious and expensive separation of Uranium-235 from the more common form Uranium-238 with which it is normally mixed. From that stage on, a mixture of motives appears to have operated. Prof. Thirring of Vienna, an open anti-Nazi who lost his university post on that account, has stated that the best of Germany's physicists had felt that it would be a "crime" to provide Hitler with an atom bomb. Prof. Heisenberg writes more cautiously of the wish of the scientists concerned to keep developments in their own hands, and their prejudice in favour of the power application In any case, as he admits, the final decision was removed from them by the hard facts that the Nazi leaders would permit no research effort which did not promise early application, and that in a Germany which was at war and beginning to feel the weight of an air offensive, the scale of effort applied in the United States would not have been possible. There were discussions with the naval authorities on the possible application of atomic energy for the propulsion of naval vessels—which would have been able to remain at sea for long periods without refuelling—and only limited research on the scientific side. None the less the position at the end of the war was that a small nuclear pile had been completed, which would have functioned in all probability as a self-sustained source of power, if only a relatively small amount of pure uranium metal had been available. Incidentally, there seems to have been no difference in principle between this pile and those designed in the United States, so that the assumption made by many of the more vociferous in that country that no one else knew anything about atomic energy is patently proved absurd. It is also of interest, in connection with this German approach, that one of America's leading electrical engineers has lately expressed the opinion that the propulsion of large ocean-going vessels, merchant as well as naval, well provide the first "genuinely commercial" ...

of atomic energy He agrees, however, that the use of atomic energy on land, as a supplement to other sources of power, will come more quickly in countries where fuel is either expensive or in short supply. Britain can certainly fulfil the second of these requirements.

See Heisenberg, *Nature*, 1947, pp 160, 211, Winne, *Electrical Eng*, 1947, pp. 66, 631.

Radioactive Catalogue

Apart from various nuclear investigations which will be of value in the final design of the larger nuclear pile at Harwell, which is expected to be ready some time in 1948, the existing "Gleep" will be used in the interval to supply small quantities of artificially radioactive materials for research use. It has been stated by Dr. Cockcroft that Harwell proposes to make and supply all radioactive forms which have already been listed as "on the market" in the United States, and in addition to offer what can best be described as a "consumer demand" service The order of priority will be Harwell's own requirements first; university laboratories next; and other research laboratories, including those of industry, third. Such, at least, will be the general policy. In detail, allocations will be administered by a committee, which will be in a position to treat individual cases on their merits, and on which the Medical Research Council, among other bodies, will be represented Ability to take adequate safety precautions is likely to be made an absolute requirement. One suggestion is that joint local committees should be set up to settle the possibly invidious question of what laboratories are, and are not, equipped to handle radioactive substances. Detailed standards have also been worked out at Harwell to ensure safety in transit. Photographic film will be used to give a final overall check of the amount of radiation which is penetrating the protective lead casing; and there will be a limitation on the number of "cans" that may travel together.

We Are All Radioactive

Examples continue to multiply of research uses—mainly, as might be expected, from the United States, where the supply position is relatively good One of the most intriguing is due to a research team led by Prof. W. F. Libby of the University of Chicago. He has found that all living things are in a very small degree radioactive. The argument which led him to this particular piece of research began from a quite natural speculation—to one versed in atomic energy—as what the effects on the atmosphere might be of the neutrons which cascade through it as a part of cosmic radiation from outer space. Even before the war, it was known from the work of Prof. Enrico Fermi (whose name is now associated with the design of the nuclear pile) that neutrons were an extremely effective agent in bringing out atomic transmutations. And, after the demonstration of this fact given on an engineering scale, first in the nuclear pile, and later in the atom bomb, it was natural to consider what changes the atoms of the air might be expected to undergo from the similar, but less intense, treatment to which they are continually exposed. Prof. Libby concluded from the known results of laboratory experiments, that the most likely change was the conversion of atmospheric nitrogen into radioactive carbon. As the average life of a radio-carbon atom is some seven thousand years, he saw further that this radio-carbon would have plenty of time in which to be absorbed from the air by plants in the form of carbon dioxide, built up by plants into sugars and proteins; eaten by animals and incorporated into their own bodies; and either be breathed out again into the air as carbon dioxide, or else find its way into the sea or soil. From such data as were available, he predicted that all carbon derived from living forms—or equally from the air, sea or soil—would be found to be radioactive to the of between 1 and 10 disintegrations per gram weight minute. This is a fantastically small amount of activity to seek to demonstrate But by laboriously,

trating the radio-carbon obtained, in the form of methane, from the Baltimore City sewage works, Prof. Libby has been able to confirm that the predicted radioactivity of organic carbon is a real phenomenon. As a check, he attempted to apply the same process to other samples of methane from petroleum, which has been long enough below ground to have lost any radioactivity it may once have possessed, but in this case no amount of concentration produced any measurable effect. It looks, therefore, as if we are all, as Prof. Libby predicted, a little radioactive, and that this radioactivity is derived in the first instance from whatever cataclysms in stars or space give rise to cosmic radiation It is a majestic conception, which it is something of a technical triumph to have been able to confirm; and, if Prof. Libby's work does nothing else but draw attention in dramatic form to the reality of the "carbon cycle" on which all life ultimately depends, it will probably have been worth while But it has no bearing whatever on, for example, the *practical* problems of plant nutrition. Plants get the carbon they need from the air.

See Libby, *Phys Rev*, 1946, pp 69, 671, Anderson, Libby, Weinhouse, *et al*, *Science*, 1947, pp 105, 576

Research Uses

Other and more practical uses of radio-activity in physics and industry have been discussed at a conference held by the Institute of Physics, against the day when Dr. Cockcroft will be able to make supplies more readily available. The method is the same, in principle, as that used in the United States studies of blood storage and transfusion which were mentioned in *Science News* 2. The point in each case is that radioactive atoms take part in the same chemical and physical changes as do normal stable atoms of the same chemical element; but, because of their radioactivity, can be followed, with no room for argument, wherever they may go. In one engineering application, mechanical wear has been studied in moving machinery by incorporating

suitable radio-elements in test alloys, and then looking for whatever radioactivity may have been imparted to the lubricating oil along with the usual metallic dust. In another, the radio-element used as a "tracer" has been employed to measure the efficiency with which smoke filters were preventing the passage of fine dust. Still another application has been in the study of flow patterns in the ducts carrying furnace gases. Tackled by normal methods, this would involve measurements of the rate of diffusion of gases under turbulent conditions, which cannot easily be carried out, although it is clearly of practical value to the designer to know the form which the flow patterns take under different conditions. Finally, and as an example of quite a different kind of use, it has been found useful in a fire precaution to incorporate small amounts of radioactive material in the running belts of grain elevators. The point, in this case, is that a mixture of grain particles and air can form an almost explosive mixture, so that any sparking due to the electrical charge built up by friction on the running belts could be dangerous. The effect of the radioactivity is to ensure that any electric charge on the belts leaks away smoothly and continuously, without ever reaching the danger level. The possibilities offered by these new radioactive materials in "pure" research are undoubtedly more important; but these practical and engineering examples give, somehow, a reassuring impression of reality.

See Institute of Physics Conference on Applications of Radioactive Tracer Research and Industry, 1947. *J. of Scientific Instr*, in the press

Alloy Research

Apart from obvious and immediate efforts to produce new alloys capable of withstanding, for example, the impact of hot and high-speed combustion gases in a gas turbine, without either corrosion or loss of rigidity, there has been a good deal of alloy research lately of a more fundamental kind. And it may be worth emphasising that it is from such

been the discovery of a hitherto completely unknown stream of meteors at the Jodrell Bank Experimental Station of the University of Manchester. This is under the immediate direction of Dr. A. C. [redacted] Lovell, who was one of our radar scientists during the war, but forms part of the physics department of which Prof P. M. S. Blackett is the head There are several unusual points about these meteors. The first and most striking is that they are a "daylight stream," which from the nature of the case could not have been detected by the normal method of visual observation This division into night streams and daylight streams arises from the fact that, whereas the earth's orbit round the sun [redacted] not very far from circular, the orbits of meteors are for the most part highly eccentric, passing very much closer to the sun than we do at one point, and at the opposite extreme travelling out into more distant regions of the solar system. Ignoring complications, this means that the meteors of any particular stream may approach the earth from either of two different directions. They may be detected, as in the normal cases, when they are moving in towards the sun, and so approach the earth on the side which is in darkness, or, as has now been made possible by radar, they can be picked up when they are moving out from a point near the sun, and so reach the earth on the "daylight side." There is therefore a special interest in the detection for the first time of a stream of this kind. It is something which could not before have been done. The second interest of these new meteors is that the stream of

orbit round the sun. The new meteors, on the other hand, although first observed in May, were still going strong in July; and for about two months the maximum daily count rate never fell below the figure of twenty meteors an hour which has already been quoted in the case of the Geminids. This implies a spreading out of the meteor stream to an extent which has never before been observed, and will give the astronomers who are now at work on the results some quite difficult problems in interpretation. The usual, but unproved, assumption is that each of the main meteor streams which the earth encounters is associated with some particular comet. The basis for this belief is that they appear to follow closely similar orbits, and the fact that the comet itself is only seen once in each revolution round the sun, whereas the meteors are seen annually, is explained by supposing that the latter have become spread out lengthwise round the entire orbit which they follow, as sometimes happens with athletes in a long-distance race Knowledge of this kind of spreading out is dependent, naturally, on looking for the same meteor stream year after year, and finding that some of its representatives always turn up The spreading out which has been observed in the new meteor stream is, as it were, sideways. It is as if the track itself had been broadened out—and that to the extent of about one hundred million miles, or more than one-sixth of the earth's total orbit round the sun. For this reason, there is some doubt as to whether the whole of the new meteors can be associated with a single comet. A possible alternative is that the orbits of two or more different meteor streams may pass close together, giving the impression where they cross the earth's path of a single stream If all the meteors "belong" to a single comet, it is probably Halley's, the most famous of them all.

See British Astr Ass. Circular, 1947, No 282

The Aurora Borealis

The Aurora Borealis, long admired by visitors to northern

latitudes as one of the most impressive of natural spectacles, is also one of the best available methods of studying the upper atmosphere. Physicists, incidentally, prefer the description Aurora Polaris, since Borealis means northern, and these displays of luminous arcs, bands and curtains are as characteristic of southern polar regions as of the north In either case they are believed to be due to the impact of electrically charged particles on the earth's atmosphere—the effect of the earth's magnetism being to guide these particles towards either the north or south magnetic poles.

To the meteorologist, in the long run in relation to weather forecasting, the chief claim of the Aurora to interest is that it affords the one means available—short of high altitude rockets—of studying the whole range of the earth's atmosphere from about 60 to about 600 miles above the earth. Several different lines of approach are possible. The oldest, due to Professor Störmer of Oslo, is the systematic collection of the heights of Auroral displays, by simultaneous photography from two or more stations. From his network of stations in southern Norway, he has now some 12,330 measurements of height at his disposal, and he reckons that a further 8,000 heights can be secured from existing photographs He has, therefore, published a first analysis of all these observations, and is now setting systematically to work to secure the greatest possible information from the large mass of photographs already taken.

A second approach, in which the French school of physicists has long specialised, is the detailed study of the radiation produced not only by the Aurora itself but also, although at very much less intensity, by the normal night sky. This has shown that the chief components of the upper air are oxygen in the atomic state, nitrogen as at ground level, and possibly some few other elements, including sodium believed to be derived from meteors. Much work of this kind was discussed at an international conference

which was held lately in London by the meteorological research committee of the Royal Society.

Still more lately, Dr. A. C. B. Lovell, of the University of Manchester (whose work on meteors was mentioned in the preceding paragraph) has found that radar methods can also be applied to the Aurora. At the Jodrell Bank Experimental station near Manchester, he has obtained radar echoes during last summer from a luminous cloud at the tip of one of the well-known Auroral streamers. He was able, in addition, to measure the electrical state of the cloud, and to compare this with that of "normal" air at the same time and height. He found that the number of free electrons in the cloud was roughly one hundred times as great. Although clearly of more use to Professor Störmer in Norway than in England, it would seem therefore that a valuable new method of studying the Aurora has been discovered.

See Störmer, *Terrestrial Magnetism*, 1946, pp. 51, 501; Lovell, Clegg and Ellyett, *Nature*, 1947, 160, 372.

New Law of Magnetism

The magnetism shown by the earth, and as soon as it could be measured by the sun also, has long presented a problem to physicists and astronomers. The fact that the line joining the north and south magnetic poles of the earth is in roughly the same direction as the line joining the two geographical poles carries an obvious hint that the earth's rotation may have something to do with its magnetism. And, as long ago as 1891, it was suggested that it might be the cause of it. At this time, there was no other large and rotating body with which comparison could be made; and there was also the quite formidable difficulty that the earth's magnetic axis was in a direction ten degrees different from its axis of rotation. This meant that even if the rotation of the earth was a main cause of its magnetism, it would still be necessary to provide a second theory which would explain the discrepancy. Then, in 1910, the

measurement was made of the magnetism of the sun. In this case, too, it was found that the magnetic axis corresponded nearly, but not quite, with the axis of rotation. The discrepancy was a little less, about four degrees instead of ten, but still large enough to require explanation. Thus the position remained until the beginning of the present year, when Dr H. W. Babcock of Mount Wilson Observatory, California, published the results of the first measurements which have been made of the magnetism of a star. As it happened, Prof Blackett of Manchester was already interested in the problem, since the earth's magnetism had affected his own work on cosmic radiation. Not all of the particles found in cosmic radiation are electrically charged. But the effect of the earth's magnetism on those particles which are electrically charged is to cause them to approach the earth along a spiral course, with the slower-moving particles making predominantly for one or other of the magnetic poles The point, in the present connection, is that Prof Blackett had already been used from his own work to thinking about the earth's magnetism; and being a physicist, he thought in general terms, rather than special and elaborate explanations based on speculation as to what might be going on within the earth's crust With this approach, he was struck by the fact that, in the case of the earth and the sun, the "strength of magnetism" (magnetic moment) of these two bodies was proportional to their angular momentum—the latter expression meaning, in effect, the time for which a specified braking force would have to be applied, at the same distance from their centres, to bring them to rest. "Quantity of rotation" is another way of expressing the same quantity. It depends, in any case, on three factors—mass, rate of angular rotation, and degree of compactness; and is about ten million times greater in the case of the sun than in the case of the earth. Having got so far already, Prof. Blackett was naturally quick to test his ideas against Dr. Babcock's measurements of the magnetism of the star, 78 Virginis, as soon as these

were available. Compared with the sun, he found that both the magnetism and the angular momentum of this star were increased in about the same proportion, and by a factor of some hundreds. He has suggested therefore, as a new law of nature, that any massive and rotating body is automatically a magnet, in virtue of its rotation; and that these two quantities, magnetic moment and angular momentum, are always proportional to one another. This, if true, is a very remarkable conclusion. So far, it rests on three cases only. The further possibilities are: First, confirmation from other stars; and, second, which would be much more convincing and satisfactory, that by rotating a sufficiently large bronze sphere at a high enough rate, it might be possible to demonstrate the same effect in the laboratory. The indications are that the magnetism due to the rotation of such a sphere should be just, but only just, detectable. It should be added that some few weeks after Prof. Blackett's announcement in England, Dr. Babcock put forward similar ideas in the United States

See Blackett, *Nature*, 1947, pp. 159, 658, Babcock, *Astrophys, J.*, 1947, p. 105.

The Heat Pump

Anything which can lead to a saving of coal is of obvious importance under present conditions both in Britain and in Europe as a whole. Also, and apart from any immediate shortage in supplies, it is clear that as wage standards and living conditions are improved, it becomes economic to spend more money on capital equipment which will lead to fuel economy. It is for these two reasons that engineers have lately been taking increased interest in a device which, although generally unfamiliar, has been recognised as a theoretical possiblity for more than a century This is the "heat pump," no longer an idea, but a practical engineering device It has been used by Mr J A. Sumner, City Electrical Engineer to the Corporation of Norwich, to heat his o headquarters building through two winters, and has b

plastics industry. More to the point, it has been found that crude uncrystallised cane sugar can be used as the raw material. Also, since the processes involved are comparatively simple, it should be possible for manufacture to be carried out in the countries of origin.

Another of the Council's proposed activities is the establishment in Trinidad of the first research institution *in the British Commonwealth solely devoted to microbiology*—the study, that is, of moulds, bacteria and other primitive forms of life. It is a branch of science which jumped from neglected obscurity into sudden prominence with the development of penicillin; but in fact it has long been known that the flavour of, for example, tea, cocoa and tobacco is greatly affected by the action of micro-organisms, not *necessarily for the worse*, while in other cases they are responsible for serious plant diseases. One such is the notorious Panama disease of bananas, which may well prove critical for the banana industry of the West Indies. A recent discovery, which may be hopeful, is that a primitive soil fungus, also first isolated in the West Indies, can destroy the organism which causes the disease. This is being jointly investigated by a team of chemists at the Imperial College of Science and Technology in London, and on the biological side by Dr A. C. Thaysen who will be the first director of the Trinidad Institute.

See Simonsen, *The Advancement of Science*, 1947, pp. 4, 166.

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